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# Final Environmental Impact Statement for a Possible Regime for Conservation of Antarctic Living Marine Resources

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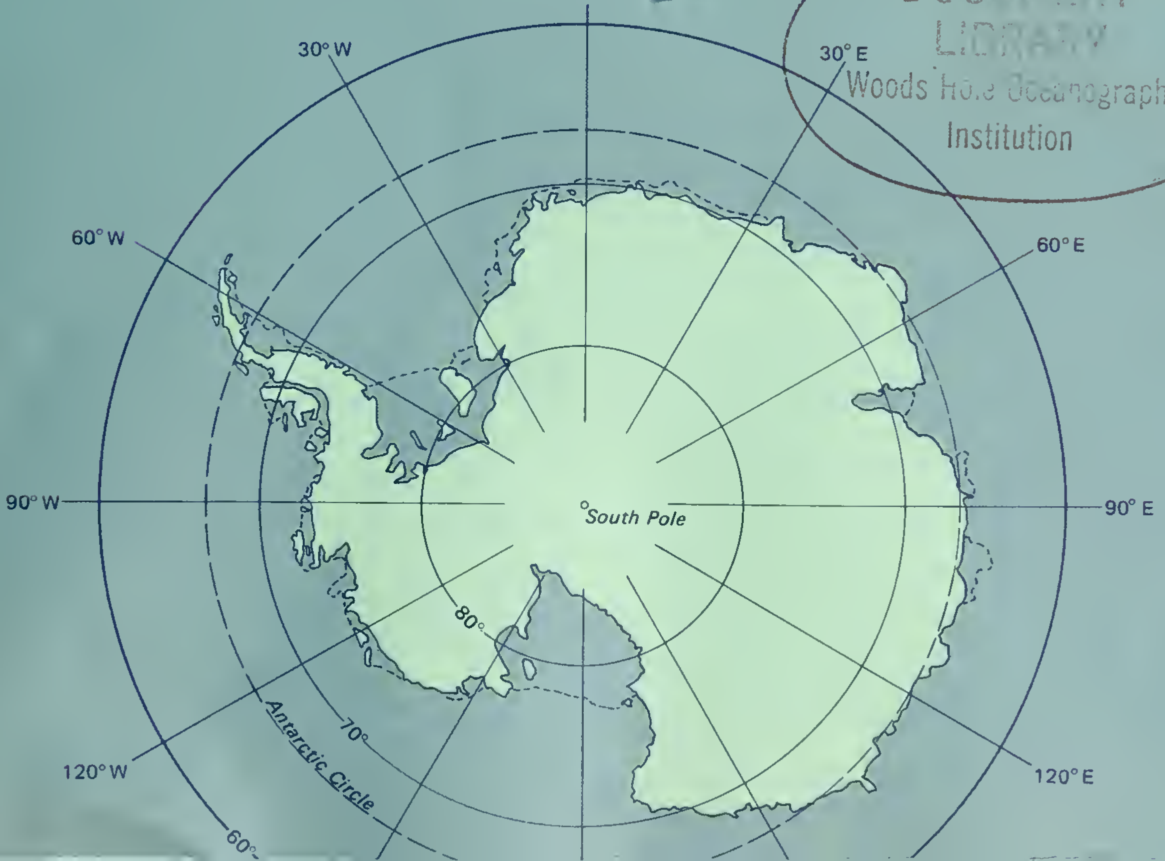

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DEPARTMENT OF STATE

# FINAL ENVIRONMENTAL IMPACT STATEMENT ON THE NEGOTIATION OF A REGIME FOR CONSERVATION OF ANTARCTIC MARINE LIVING RESOURCES

June 1978

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## SUMMARY

STATEMENT TYPE: Final Environmental Impact Statement
PREPARED BY: Department of State

(Attention: Mr. William Mansfield, III
Office of Environmental Affairs
(Room 7820)
Department of State
Washington, D. C. 20520)

1. Type of Action: Negotiation of a treaty

2. Brief Description of Proposed Action:

The United States will participate in the negotiation of a regime to conserve Antarctic marine living resources. All living resources in waters south of the Antarctic Convergence, except whales and except seals south of 60 degrees south latitude, are affected. The purpose of the regime would be to ensure that any harvesting of Antarctic marine living resources take place in accordance with sound conservation principles. There are no present or proposed commercial fishing operations by the United States in Antarctic waters.

3. Summary of Environmental Impacts and Adverse Environmental Effects:

Commercial harvesting will result in the continuing and increasing removal of fish and krill from Antarctic waters. Future harvesting may include squid, birds and seals as well. It is anticipated that krill will be the most heavily exploited resource. Populations of organisms which feed on krill and are themselves potentially harvestable resources will be reduced as krill availability declines due to harvesting. The recovery rate of protected baleen whale species may be slowed. Under the proposed conservation regime, harvesting would be regulated to minimize the impact on the Antarctic ecosystem. The adverse impacts of a controlled harvest would be considerably less than impacts of uncontrolled harvesting which is anticipated in the absence of an international agreement on a conservation regime. Increased harvesting will increase shipping traffic in the Antarctic region. Ship or shore based factory facilities may cause local pollution problems. Increasing human activity will increase disturbance of the Antarctic marine ecosystem which is of scientific interest in part because it is the least disturbed of marine habitats. The proposed conservation regime, if effective, will moderate adverse environmental impacts in accordance with the objective of maintaining the health and long term productivity of the Antarctic marine ecosystem.

4. Summary of Major Alternatives Considered:

Alternatives to the proposed negotiation of a complete conservation regime are: (a) to seek no action to conserve Antarctic living resources, (b) to pursue national action for conservation of Antarctic resources with coordination among nations, (c) to negotiate an international agreement to collect, exchange and analyze data on the Antarctic ecosystem with a commitment to later establishment of a conservation regime, (d) negotiation of a conservation regime, plus imposition of specific conservation measures in the language of the agreement or imposition of a moratorium on harvesting until such measures are developed, and (e) to negotiate an agreement prohibiting all harvesting of living resources in Antarctic waters.

5. Agencies and Parties from Which Comments Have Been Requested:

Comments on the draft statement were received from the following:

Federal agencies and Offices:

U.S. Arms Control and Disarmament Agency
Central Intelligence Agency
Department of Commerce
  National Oceanic and
  Atmospheric Administration
Council on Environmental Quality
Department of Energy
Department of the Interior
Marine Mammal Commission
National Science Foundation
Department of Transportation
  U.S. Coast Guard

Private Organizations:

American Cetacean Society, Orange County, Ca. Chapter
Center for Law and Social Policy
Committee for Humane Legislation, Inc.
International Institute for Environment
  and Development

Monitor (Comments endorsed by:
  Society for Animal Protection Legislation
  Animal Welfare Institute
  Humane Society of the United States
  International Fund for Animal Relief
  Rare Animal Relief Effort
  Washington Humane Society
  International Private Protection League
  Fund for Animals
  Defenders of Wildlife
  Sierra Club
  Let Live)
National Audubon Society
New York Zoological Society

Individual Comments:

David G. Ainley, Ph.D., Point Reyes Bird Observatory
J.R. Beddington, University of York, England
Hugh H. DeWitt, University of Maine
M.D. McWhinnie, Ph.D., DePaul University
Donald A. Scott, Oceanographic Services, Inc.
Drs. Rudiger Wolfrum and Frederick S. Tipson,
  University of Virginia

6. Date Draft Statement made available: February 1, 1978
   Date Final Statement made available: June 17, 1978

7. Preparation: The draft and final environmental impact statements were prepared by Katherine A. Green, Ph.D. in cooperation with officials of the Department of State.

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## I. PROPOSED FEDERAL ACTION

### A. Description

The proposed Federal action is the negotiation of a regime to conserve Antarctic marine living resources through conclusion of an international agreement. The international agreement, anticipated to be a treaty, would set forth the objectives of the regime and provide the obligations, functions and machinery necessary to fulfill them.

The international agreement would provide that:

-- the purpose of the regime to be the conservation, including rational utilization, of Antarctic marine living resources;

-- the regime apply to the populations of all living resources of the Antarctic marine ecosystem, defined as all species, including birds, found in marine areas south of the Antarctic Convergence, and their relations with each other and with their physical environment;

-- the regime not provide for direct regulation of whales and seals already regulated by the International Whaling Convention and the Convention for the Conservation of Antarctic Seals;

-- any harvesting of Antarctic marine living resources be conducted in accordance with a conservation standard, incorporating an ecosystem approach, and reflecting the following elements:

a) maintenance of populations or species of Antarctic marine living resources at levels which offer maximum annual production on a continuing basis;

b) maintenance of the balance among the species composing the Antaractic marine ecosystem, taking into account the relationships between harvested and non-harvested species;

c) prevention of irreversible changes in the Antarctic marine ecosystem.

-- a commission of the Contracting Parties be established, with an effective decision-making system, to implement the conservation standard and undertake actions necessary to ensure the effective operation of the regime,

-- the commission develop, adopt and revise conservation measures, including total catches in the area as a whole or in subareas defined on the basis of the range of specific populations of Antarctic marine living resources; open and closed seasons and areas, protected species; gear and effort regulation and other steps necessary to fulfill the purposes of the regime;

-- a scientific committee be established to provide the commission with independent and expert advice, analyses and recommendations to the commission;

-- the scientific committee's functions include assessment of the status and trends of the populations of Antarctic marine living resources, analysis of data on the effects of harvesting on populations of Antarctic marine living resources, assessment of the effects of changes in harvesting levels and proposed conservation measures and identification of research needs and development of proposals to meet such needs;

-- the commission publish the reports of the scientific committee;

-- a secretariat be established to serve the commission and scientific committee;

-- contracting parties be obligated to provide data required by the commission and the scientific committee to carry out their functions, including regular and detailed reporting on harvesting activities carried out by their nationals and vessels;

-- any harvesting activities be carried out in such fashion to take advantage of opportunities to collect needed data on the impact of harvesting;

-- contracting parties be obligated to ensure compliance with the provisions of the convention and measures adopted by the commission;

-- a system of international observation and inspection be established to oversee compliance with provisions of the convention and measures adopted by the commission;

-- the commission and scientific committee ensure close coordination between their activities and those of the International Whaling Commission and those pursuant to the Convention for the Conservation of Antarctic seals;

-- the commission and scientific committee establish cooperative relationships with other international intergovernmental and non-governmental bodies which have responsibilities for Antarctic marine living resources, such as FAO, SCAR, and IUCN;

-- the budgetary expenses of the commission and other organs of the regime be apportioned equitably among the Contracting Parties;

-- accession to the regime be open to states engaged in research on, or harvesting of, Antarctic marine living resources;

-- issues relating to the existence and nature of maritime jurisdiction be treated in such fashion as to permit and encourage participation in the regime by all states engaged in research on or in harvesting of Antarctic marine living resources and as to protect the position of the United States regarding non-recognition of claims to territorial sovereignty in Antarctica.

## B. Concepts Underlying the Proposed Action

### 1. Health of the Ecosystem

One of the purposes of the proposed conservation regime is to ensure that any harvesting of Antarctic marine living resources is conducted in such a fashion as to maintain the health of the Antarctic marine ecosystem. Maintaining the health of the ecosystem implies preserving its overall productivity over the long term. The structure of the system should be protected by maintaining balance among component populations. The resilience of the ecosystem, or its ability to recover from unusual disturbances such as bad years, should not be reduced.

Given the crucial role of krill in the ecosystem, care must be taken that a krill harvest does not cause crashes in the populations of predators which depend on it for food. Of particular concern are baleen whale populations. Increases in those populations depend on reproductive capability and physiological condition of the animals which in turn depend on the abundance of their food supply.

All of the breeding stocks for each species of concern should be maintained in a robust condition. In the Antarctic as in other ocean areas, there are natural variations in climate which have negative effects on populations. Unusually warm years,in which pack ice extent is very limited, occur occasionally. These may affect the productivity of plants, and the food supply for zooplankton, fish and birds. In addition some populations may become more vulnerable to predators. Acceptable breeding habitat for seals may be limited. Unusually severe weather, such as prolonged blizzards, may kill all the young of the year for an entire bird rookery. In an undistrubed state, populations can recover from bad years. The size of the breeding stocks of each species should not be reduced to marginal levels where recovery from an unusual year would be slow.

For the Antarctic marine ecosystem to remain healthy, its overall productivity should be maintained. The balance between populations and hence the structure of the ecosystem should be maintained both in the system as a whole and in local areas. The inherent resilience of the system, that is its ability to recover from bad years, should not be endangered.

## 2. Conservation Objectives

In addition to maintaining the health of the Antarctic marine ecosystem, other tenets of the proposed federal action include preventing the overexploitation of any Antarctic marine living resource and ensuring that any harvesting of one species does not adversely affect the health of dependent or related species.

Understanding of the biology of the Antarctic marine ecosystem is incomplete. Populations of whales are best known,although information is by no means complete. Estimates of abundance,growth and reproduction, and mortality rates are available for the harvested species.

There is less current information on protected species in the absence of data provided by commercial catches. Abundance estimates are available for seals, but vary over wide ranges. Some information on reproductive rates is also available. However, very little is known of the distribution or survival rates of juveniles, and consequently recruitment into the breeding population cannot be predicted. Since most birds congregate on islands or the coast of the Antarctic continent for breeding, abundance estimates are available for the species and rookeries which have been studied.

Fish and squid are known to inhabit the waters, but there is no quantitative information on their abundance or productivity. Even krill, which have been the subject of much scientific and commercial interest, are not well known. Estimates of abundance and of potential yield vary widely. Breeding stocks have not been identified. Some aspects of the physiology of krill such as life span, age of attainment of sexual maturity, and number of reproductive seasons are debated.

It is necessary to recognize that information on the Antarctic marine ecosystem is incomplete and to proceed with extreme care in harvesting of any of the resources. Continual monitoring of both the harvested resource and related species is necessary to be able to understand and observe impacts on target stocks and on the rest of the ecosystem.

The proposed federal action would require that data from commercial harvesting be both collected and analyzed. It would also encourage scientific investigation.

The Antarctic marine ecosystem does have great resource potential and the resources are renewable. Another important objective of the proposed federal action is the maintenance of this potential productivity over a very long term.

In managing Antarctic resources there will be trade offs between long term and short term objectives. Intensive harvesting to produce high yields for a few years is possible with all the resource stocks, but is inconsistent with a dependable harvest over many decades.

There is a real possibility of overexploitation of fish and seal stocks given present technology. As technology for krill harvesting becomes more efficient, there is also a real possibility of overexploitation of krill even though they are very abundant. In addition, public expectation for krill harvesting is high. The most widely discussed popular estimates of potential krill harvesting are considerably higher than yields which the system could sustain over the long term (Green, 1977). It is possible that public pressure for a large short term harvest to the detriment of long term yield would be great.

One purpose for negotiating a conservation regime for Antarctic living resources is to manage for long term yield of the whole ecosystem. That will entail keeping short term harvesting below the rates which technologically are possible, in order to protect the biology of the system. Since unregulated harvesting would tend to maximize yields in the near future to the detriment of the long term productivity of Antarctic waters, a treaty or regime for long term conservation is needed.

### 3. Management Options

The proposed conservation regime will cover all species of the Antarctic ecosystem except whales which are already covered by the International Whaling Convention and seals south of 60°S latitude which will fall under the Convention for the Conservation of Antarctic Seals now that it is in force. The proposed regime will undertake management of the ecosystem as a whole, i.e. all species together, in cooperation with the bodies governing sealing and whaling. This management approach will be much more effective in maintaining the health of the ecosystem than would be management of the krill population alone. A single species management approach for krill entails a risk of endangering populations of other species which are dependent on krill for food. In addition, it would lack information on krill losses to predation which will be dependent on the sizes of predator populations. It is possible to undertake an ecosystem level approach to resource management in the Antarctic because the ecosystem is relatively simple and the food relationships and interactions among species are understood.

Similarly a separate maximum sustainable yield (MSY) determination of potential harvest for each species of commercial interest in Antarctic waters would probably overestimate the total sustainable harvest because of the close interactions among the potentially harvestable resources. Such an approach would not be compatible with maintaining balance among populations or long term productivity of the ecosystem. Instead the proposed federal action will incorporate an ecosystem management approach in which management goals will include maintaining the long term productivity of the total system and considering balances among the different resource populations.

The Antarctic marine ecosystem is defined biologically by species distributions south of the Antarctic Convergence. All waters between the continent and the Convergence are part of the ecosystem. The proposed conservation regime already specifies all waters south of the Convergence as the geographic region to be covered.

One alternative would be an agreement on conservation of resources south of 60°S latitude corresponding to the region covered by the Antarctic Treaty and the Convention for the Conservation of Antarctic Seals. However, the Antarctic Convergence falls north of 60°S latitude for most of its extent. There are areas of intense krill concentrations north of 60°S latitude in the Weddell and Scotia Seas. There are also concentrations of some fish species, elephant and fur seals, and probably some squid species between 60°S latitude and the Convergence. Effective conservation of species not restricted to the pack ice zone must include waters north of 60°S latitude.

A second alternative geographic area for a conservation regime is choice of a more northern latitude line, such as 50°S latitude, for the northern boundary. That region would include almost all of the waters south of the Convergence. However, it would include subantarctic regions as well and greatly increase the difficulties of negotiating a regime.

Although the exact position of the Antarctic Convergence does vary, it can be located with simple physical oceanographic measurements. It also has biological meaning as a boundary. Of the species which would be included in the proposed management regime only some migratory fish (M. australis and possible some Nototheniids), fur seals, and probably some squid have distributions which cross the Convergence. For most populations covered by the proposed regime, finding the species would indicate a position south of the Convergence, so that the need to pinpoint its location would be eliminated. Thus the use of the Antarctic Convergence as a boundary for the proposed conservation regime is feasible even though the boundary moves.

Within the area to be covered by the regime, it may be possible to manage populations in geographic sectors such as the six whaling regions used by the International Wahling Commission (Chapman, 1974). However, this will not be possible until more information is available on distribution and breeding stocks of the various resource populations. A management approach covering the entire southern ocean, that is all waters south of the Antarctic Convergence, as one region is the best starting point.

The proposed conservation regime includes the establishment of a body with the authority to determine conservation needs and to regulate harvesting accordingly. Some management techniques which could be used to regulate harvesting include limiting the catch of each species by total catch, by age or size class taken, by geographic area and by season. Allowable gear, total effort or total time spent in harvesting might also be regulated. A concomitant harvest of several species might be contemplated to maintain balance between populations. Introduction of a harvestable fish such as salmon into the Antarctic ecosystem to feed on krill and then in turn be harvested has been discussed (Everson, 1977). Such an introduction of species would be subject to regulation by the conservation regime. Requirements to collect and report specific kinds of catch data as well as monitoring of oceanographic parameters or population sizes of other than target species might be established. This list of potential management techniques is intended only to provide examples. It is not exhaustive, nor are all the techniques mentioned necessarily to be used.

## II. ALTERNATIVES TO THE PROPOSED ACTION

Negotiation of the proposed conservation regime may be viewed as one point on a continuum of possible approaches to Antarctic marine living resources. Six general options can be identified on this continuum. One of these includes the proposed action, the other five represent alternatives to it. They range from a no regime option to seeking a ban on all harvesting, and can be described as follows:

1. No action to seek to conserve Antarctic marine living resources.

2. National action to conserve Antarctic marine living resources, with coordination among nations taking such action.

3. Negotiation of an international agreement setting forth the obligations and means to collect, exchange and analyze data on Antarctic marine living resources, coupled with a commitment to later establishment of a mechanism to develop and implement necessary conservation measures.

4. Negotiation of an international agreement establishing a complete conservation regime, setting forth the objectives of the regime and providing the obligations, functions and machinery necessary to fulfill them.

5. Negotiation of an international agreement establishing a complete conservation regime and imposing from the beginning specific conservation measures or a moratorium on harvesting until conservation measures are developed.

6. Negotiation of an international agreement flatly prohibiting all harvesting of Antarctic marine living resources.

The proposed federal action under consideration is the fourth alternative. The implications of the six alternatives are discussed below.

### A. No Action

This alternative reflects an assumption that no regulation of the harvesting of Antarctic marine living resources is necessary, other than that which takes place or will take place under the International Whaling Convention or the Convention for the Conservation of Antarctic Seals. There is, for instance, no present information that U.S. fishermen plan to fish in Antarctic waters. The presumed potential resources, at least that of krill, are large. Economic factors and operating conditions may serve to limit the extent of commercial harvesting.

However, such a laissez-faire approach to harvesting of Antarctic marine living resources would pose the maximum risks to the Antarctic marine ecosystem and to the long term potential of that ecosystem as a source of sustained protein yields. The approach would provide neither for controls on harvesting nor for the means of developing data on the potential resources themselves. The direct dependence on krill for food by most other potential resource populations makes the dangers of overexploitation particularly acute.

A variant of the no action approach would be the postponement of efforts to deal with exploitation of Antarctic marine living resources, a no-action-now approach. This option rests on either or both of two premises. One is that the magnitude of the resource is so great that harvesting need not be regulated for some time to come. The other is that the incentives for an effective system of conservation will be greatest at some point in the future, specifically when large scale harvesting, and its implications, become a reality.

There is, however, extensive evidence, based on experience in efforts to conserve marine resources in other areas of the world, that "after-the-fact" regulation is not effective. Sustained unregulated harvesting could have unforeseen, perhaps irreversible impacts on the Antarctic marine ecosystem. Initiation of effective regulation would likely be more difficult once substantial economic stakes in uncontrolled methods of harvesting are created.

## B. National Action

This alternative rests on the assumption that regulation by individual countries of vessels and nationals under their jurisdiction engaged in exploitation of Antarctic marine living resources can provide the basis for adequate conservation of the resources.

National action could be coordinated through negotiation of commitments among the nations involved to regulate harvesting, ranging from a simple undertaking to control harvesting to an obligation to follow specific guidelines in regulating the nationals and vessels under their jurisdiction. This alternative could also incorporate informal commitments to share scientific and catch data and to report on harvesting activities with a view to ensuring sufficient coordination to prevent conflicts or overharvesting.

This alternative would seek to build an essentially voluntary system of conservation in which no nation would be bound internationally. The kinds of obligations this alternative involves could be relatively easy to negotiate.

There are, however, a number of practical difficulties inherent in this approach. It would tend to limit effective influence upon the development and implementation of conservation measures to those nations actually engaged in commercial harvesting. The voluntary nature of the system would mean that it would be less stable and could lead to application of inconsistent conservation standards to harvesting. Its impacts upon the Antarctic marine ecosystem could be quite adverse.

### C. Negotiation of an International Agreement for Collection, Exchange and Analysis of Data

This alternative would concentrate upon the first necessary steps toward providing for adequate conservation of Antarctic marine living resources: establishment of the necessary obligations and means for creating an adequate data base. It would involve setting up a scientific and information collecting organization. The alternative is based upon the assumption that it is possible to obtain early agreement on those aspects of a regime which would build the needed data base, with the corollary assumption that negotiation of a full-scale regime could prove sufficiently difficult to justify a gradualist approach.

This option would satisfy one of the major prerequisites for adequate conservation of Antarctic marine living resources, the acquisition of basic scientific data. It might set forth a commitment to establish a system for developing and implementing specific conservation measures at some point in the future. Harvesting would not be regulated until the information gathering system was set up. It could involve a high level of risk to the Antarctic marine ecosystem since there would be no firm guarantees that the necessary standards and machinery to provide for conservation measures would in fact be developed. Delay in addressing the development of conservation measures could well make it more difficult to achieve agreement on an effective mechanism.

### D. Negotiation of an International Agreement Establishing a Complete Conservation Regime

This alternative represents the proposed federal action, described in Section I, and rests on the conclusion that it is urgent to establish an effective system to ensure conservation of Antarctic marine living resources. It also reflects the assumption that the requirements of effective conservation are not incompatible with properly controlled harvesting of Antarctic marine living resources. In addition, under this approach, harvesting could take place in the interim period after the conclusion of the regime and prior to the development of conservation measures pursuant to the regime.

The question of the treatment of harvesting in this interim period can be dealt with in two ways, which comprise variants or sub-options of the proposed federal action. The first sub-option would be not to address specifically the interim period. This variant assumes that technological and other limitations will ensure low harvesting levels for the next several years. It rests on the view that a comparison of projected initial levels of harvesting with projected potential of stocks of commercial interest indicates that specific limitations in the interim period are not required. In other words, this sub-option assumes that harvesting will not reach levels which would pose threats to target species, to dependent species or to the ecosystem as a whole prior to the development of the regime's full capability to identify conservation needs and apply conservation measures. In the event that development of the conservation machinery requires many more years than presently anticipated, this variant would involve some risk of overexploitation.

The second sub-option involves negotiation, as a supplement to the international agreement, of interim measures to apply during the period after conclusion of the regime and prior to its becoming operational. Interim measures would include mechanisms for beginning to build the data base necessary for effective operation of the regime and possible interim ceilings on harvesting, at least for krill. These interim measures would be designed to reflect a conservative approach to harvesting activities during the period prior to the full operation of the system set forth in the conservation regime.

The first of these sub-options would likely provide the necessary margin of safety in avoiding harmful impacts upon the Antarctic marine ecosystem, and would be the easier to negotiate. The second sub-option would be more difficult to negotiate but would reflect a more cautious and conservative approach to exploitation of resources, such as krill, with which there is little international experience. For this reason, the second sub-option or variant, providing for the interim measures approach described above, is preferred.

### E. Negotiation of an International Agreement Establishing Specific Conservation Measures or a Temporary Moratorium

This alternative would involve negotiation in the international agreement of specific conservation measures for some or all Antarctic marine living resources or a moratorium on harvesting until such measures can be developed. It would imply a conservation regime similar to that in the proposed federal action. The alternative would differ from the proposed federal action in one of two ways:

-- the agreement would set forth detailed conservation measures for some or all species, rather than provide for interim catch limitations or for other specific initial conservation measures to be developed by the organization established pursuant to the regime, or

-- the agreement would impose an obligation to abstain from harvesting until the conservation regime became fully operative rather than permit harvesting to take place while conservation measures were being developed.

This approach would pose fewer risks to the Antarctic marine ecosystem than the previous alternatives, including the proposed federal action. However, it suffers from several major drawbacks. There is insufficient data upon which to base specific conservation measures. An attempt to do so *ab initio* could significantly decrease incentives for nations with harvesting interests to participate in the conservation regime. A moratorium on harvesting until sufficient data is developed suffers to an even greater degree from the same negotiating disadvantages. Since a small controlled catch of krill and other species would provide data on size and distribution of stocks which are required for proper management but not presently available, a moratorium would increase the difficulty of determining necessary conservation measures. It would be extremely difficult to determine when sufficient information existed to justify lifting the moratorium. A fixed time period for the moratorium might be considered equally arbitrary.

An effective conservation regime should include all states engaged in harvesting. This alternative risks losing the participation of such countries, thus leading to a less effective system than that of the proposed federal action.

### F. A Total Ban on Harvesting

Maintenance of the Antarctic ecosystem in its present state would require a prohibition on all harvesting of Antarctic marine living resources. From the conceptual point of view, this approach obviously offers the maximum degree of protection to that ecosystem.

Seeking a ban on harvesting would ultimately represent a judgement that the health of the Antarctic marine ecosystem can be ensured only by its total insulation from human activity. By contrast, the proposed federal action is based upon the assumption that properly controlled harvesting of Antarctic marine living resources is consistent with maintenance of the health of the Antarctic marine ecosystem.

Further, a total ban on harvesting stands no chance of being negotiated. States interested in commercial harvesting would have no incentive to accept this alternative, and as a practical matter, it would be equivalent to no regulation whatsoever.

Preservation of the Antarctic marine ecosystem as a sanctuary or a relatively undisturbed natural habitat free from commercial harvesting is an unobtainable objective.

### G. Area Covered by the Regime

There is a subsidiary set of alternatives concerning the geographic area to be covered by the regime. The conservation regime of the proposed federal action would apply to the species which comprise the Antarctic marine ecosystem. The Antarctic marine ecosystem is generally considered to be geographically defined by the Antarctic Convergence which shifts in space on a seasonal basis. Linking the regime to the species which are found south of the Convergence best provides for coverage of the full ecosystem.

There are two alternatives to this approach based on geographic limits, which would provide for enforcement of conservation measures. The first is to limit the regime to the area of the Antarctic Treaty, south of 60°S latitude. Such a result could be the easiest to negotiate, at least among the Antarctic Treaty Parties. However, it would seriously compromise the effectiveness of conservation measures. Since the Antarctic Convergence lies significantly north of the Treaty area in a number of places, areas of important concentrations of Antarctic marine living resources would not be covered.

A second possibility would be to fix a geographic limit for the applicability of the regime sufficiently far north to ensure that all areas south of the Convergence were covered. The difficulty with this approach is that it would cover species not part of the Antarctic marine ecosystem and thus create difficult technical and political obstacles to negotiating the regime.

## III. RELATIONSHIP OF THE PROPOSED FEDERAL ACTION TO INTERNATIONAL AGREEMENTS WITH IMPLICATIONS FOR THE ANTARCTIC ENVIRONMENT

### A. Agreements Pertaining to the Antarctic Region

The Antarctic Treaty reserved for peaceful uses the Antarctic continent and ice shelves, south of 60°S latitude. It encourages scientific investigation and provides for exchange of information. It further provides nothing in the treaty shall prejudice or in any way affect the rights, or the exercise of rights of any State under international law with regard to the high seas within the Treaty area.

In addition to the Antarctic Treaty itself, the United States is a party to several agreements which directly concern the environment of Antarctica. The Agreed Measures for the Conservation of Antarctic Fauna and Flora (not yet in force, but effectively adhered to as voluntary guidelines by the Treaty Parties) provide a stringent system of protection of native mammals, birds and plants and establish certain "Specially Protected Areas" which are to be accorded special protection in order to preserve their unique natural ecological characteristics. The Agreed Measures pertain to areas and species on the Antarctic continent and pack ice. The International Whaling Convention regulates whaling in Antarctic waters. The Convention for the Conservation of Antarctic Seals, opened for signature in 1972, entered into force on March 11, 1978. It applies south of 60° latitude.

The Convention on International Trade in Endangered Species of Wild Fauna and Flora entered into force 2 June 1975. The Convention provides for the identification of endangered species and the prohibition in international trade in such species or products made therefrom. It applies to two species of whale -- the blue and humpback whale -- found in Antarctic waters. These whales are also protected species (no commercial harvesting) under the International Whaling Convention.

### B. Agreements Pertaining to the Marine Environment

In addition to the foregoing international agreements, a number of international conventions dealing with protection of marine environment, primarily from vessel-source pollution, would apply to Antarctic waters. Regulation of discharges from vessels and provision of liability for damages and clean-up costs for spillages of oil into the

the marine environment are the subjects of the following conventions negotiated within the Inter-governmental Maritime Consultative Organization (IMCO):

-- The International Convention for the Prevention of Pollution of the Sea by Oil, 1954 as amended in 1962 and 1969. (Ratified by the U.S., entered into force 20 January 1978).

-- The International Convention for the Prevention of Pollution from Ships, 1973. (Not ratified by the U.S., not yet in force).

-- The International Convention on Civil Liability for Oil Pollution Damage, 1969. (Not ratified by the U.S., entered into force 19 June 1975).

-- Protocol to the International Convention on Civil Liability for Oil Pollution Damage, 1979. (Not ratified by the U.S., not yet in force).

-- International Convention Relating to Civil Liability in the Field of Maritime Carriage of Nuclear Material, 1971. (Not ratified by the U.S., entered into force 15 July 1975).

-- The International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage, 1971. (Not ratified by the U.S., not yet in force).

-- Protocol to the International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage, 1971. (Not ratified by the U.S., not yet in force).

International regulations of the intentional disposal of matter at sea (which again applies to Antarctic waters) is provided for in the Ocean Dumping Convention (the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, of 1972) which the U.S. has ratified and which entered into force on August 30, 1975.

The commitments which would be undertaken by parties to the regime proposed in the federal action would be entirely consistent with the obligations under the international agreements listed above. The legal instrument setting forth activities pursuant to the regime with those pursuant to the International Whaling Convention and the Convention for the Conservation of Antarctic Seals (when in force). In addition, it would be desirable to provide specific reference to the Agreed Measures for the Conservation of Antarctic

Flora and Fauna in the legal instrument to ensure that measures pursuant to the Agreed Measures are properly taken into account.

### C. Fisheries Bodies

There are several fisheries bodies with which a regime to conserve Antarctic marine living resources might have specific relationships. These include the Regional Fisheries Advisory Commission for the Southwest Atlantic, the Indian Ocean Fishery Commission, the Indo-Pacific Fisheries Council, the International Commission for the Southeast Atlantic Fisheries, and the Permanent Commission of the Conference on the Use and Conservation of the Marine Resources of the South Pacific. The first three bodies were created under the auspices of the United Nations Food and Agriculture Organization (FAO), the other two purusant to separate international agreements.

The proposed federal action would provide for establishment of cooperative relationships, where appropriate, with those bodies. This could be accomplished through the close working relationship anticipated with FAO, supplemented if and where necessary with ties to any of the individual fisheries bodies.

## IV. RELATIONSHIP OF THE PROPOSED FEDERAL ACTION TO DOMESTIC LEGISLATION WITH IMPLICATIONS FOR THE ANTARCTIC ENVIRONMENT

There are two domestic acts which bear upon species covered by the conservation regime set forth in the proposed Federal action: the Endangered Species Act of 1973 and the Marine Mammal Protection Act of 1972.

The Endangered Species Act of 1973 incorporates and expands authority under previous endangered species legislation to identify fish and wildlife threatened with extinction and to prohibit their importation into the coastal States. The 1973 legislation gives consideration to all animal life, not only the vertebrates, mullusks and crustaceans included under the previous law, and recognizes the importance of wild plants as well as animal species. It provides for protection of "threatened" as well as "endangered" species, permitting preventive action before a critical stage is reached and thereby enhancing the likelihood of successful recovery. It authorizes a grant program to assist state endangered species programs, and provides for Federal protection of resident species where states are unable to do so. It requires coordination among all Federal agencies whose activities may impact threatened or endangered species or their habitats, and directs these agencies to use their other authorities in furtherance of the purposes of the Act.

Species found in Antarctic waters listed as endangered under the U.S. Endangered Species Act are the blue whale, humpback whale, sei whale and sperm whale. (The sperm whale is not listed as endangered in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Sei whales other than the North Pacific stock, are not listed as endangered under CITES, but are listed as stocks to which special controls should apply.)

The Marine Mammal Protection Act of 1972 gives special domestic protection to marine mammals, including whales. The Act prohibits the taking or importation of such mammals and their products by U.S. citizens. The Secretary of Commerce or Interior, depending on the species, can waive this prohibition only if he receives scientific evidence that the waiver and the regulations on takings that he must develop after a formal hearing, will not be to the disadvantage of the species or stock to be taken. The Act calls for negotiations to develop international programs for the protection and conservation of marine mammals covered by the Act.

The conservation regime set forth in the proposed Federal action would be consistent with the purposes of both the Endangered Species Act and the Marine Mammal Protection Act.

# V. DESCRIPTION OF ENVIRONMENT

## A. Physical Environment

Surrounding the Antarctic continent is a ring of ocean contiguous with the Atlantic, Pacific and Indian Oceans to the north. The Antarctic Convergence is the northern boundary of Antarctic waters. Waters north of the Convergence are subantarctic. The average ocean area south of the Convergence is 38 x $10^6$ $km^2$ (El-Sayed, in press).

### 1. Antarctic Convergence

The Antarctic Convergence is a boundary between different water masses. South of the Convergence water surface temperature drops 2 to 3°C. The exact geographic location of the Convergence varies with changing thermocline and wind stress conditions, but it can be located with temperature and salinity measurements.

The Antarctic Convergence also known as the Antarctic Polar Front Zone, is not a very sharp boundary, but actually is a transitional zone between water masses. It is a characteristic of surface water masses, having a depth of up to 600 meters. The deep northward flowing Antarctic bottom water flows underneath the Convergence (Gordon, 1971). The Antarctic Convergence is not a boundary for deep living organisms such as bathypelagic fishes.

A map of the southern ocean showing the position of the Convergence and other features is given in Figure 1. The Convergence lies approximately along 50°S latitude in the Indian and Atlantic Ocean sectors. In the Drake Passage it lies approximately halfway between the tip of the Antarctic peninsula and the tip of South America. In the Pacific sector it lies approximately between 55°S and 60°S latitude (Mackintosh, 1972). The Convergence is a physical oceanographic boundary. It is also a faunal boundary. Biological communities south of the Convergence are distinct from those north of it (Marr, 1962; Hasle, 1968).

### 2. Currents

Surface currents flow latitudinally in the southern ocean. Near the continent water flows toward the west and is known as the East Wind Drift. North of approximately 60°S latitude water flows toward the east and is known as the West Wind Drift or the Circumpolar Current. There is a gyre circulation pattern in the Weddell Sea extending from the Antarctic peninsula to almost 30°E longitude (Foster, in press) which seems to coincide with some species distributions (Everson, 1977). There are other gyres in the Bellingshausen and Ross Seas. Plankton are transported by water currents.

### 3. Ice

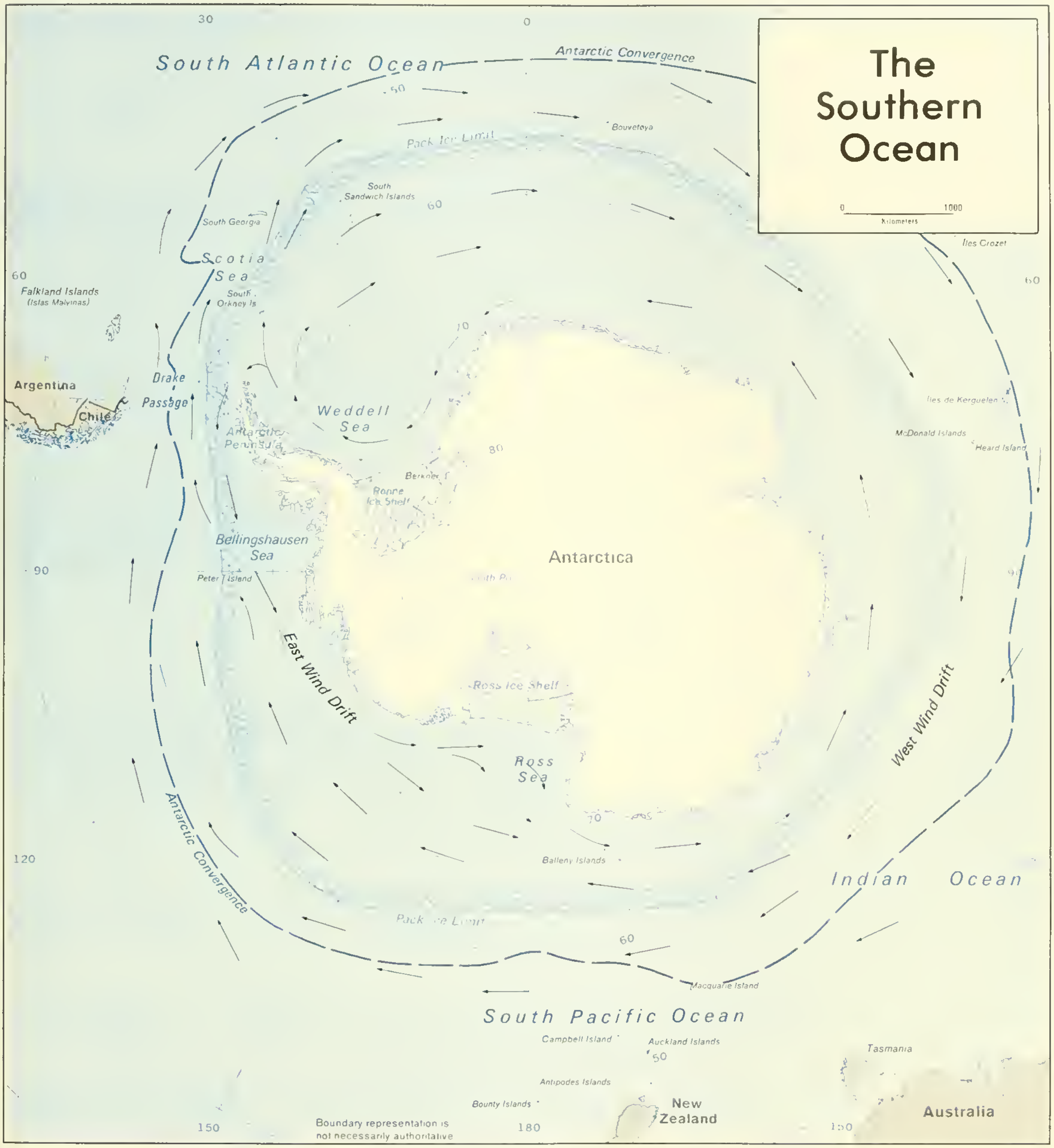
Seasonal variation in the ice cover characterizes the southern ocean. Large icebergs form from calving of the tongues of glaciers. Since bergs extend deep into the water, their movements are determined by patterns of water currents. The much more extensive sea ice which covers enormous areas of ocean surface is formed by the freezing of sea water and is known as pack ice. It averages about 1 meter in thickness, and its movements are determined by wind patterns.

The pack ice extends northward from the continent with a maximum areal extent of approximately $25.5 \times 10^6$ km$^2$ in the winter and a minimum of about half that or $13 \times 10^6$ km$^2$ in the summer (Mackintosh and Brown, 1956). Thus the Antarctic continent appears to pulsate. The total extent of the pack ice varies from year to year. The outer edge of the pack ice is always several degrees of latitude inside the Antarctic Convergence (Mackintosh, 1972).

The pack ice provides habitat for seals and penguins. Most of the pack ice melts during the summer and so has a maximum age of one year. Some multi-year ice is found in the Weddell Sea where gyre circulation prevents it from moving northward. Areas of pack ice in February and March (late summer in the southern hemisphere) in the eastern Ross Sea and along much of the coast of the Antarctic continent presumably are population centers for pelagic seals (Gilbert and Erickson, 1977).

As the pack ice expands and contracts, it covers and uncovers krill and other nonmigrating populations. There is intense biological activity at the edge of the pack ice where primary productivity is high. Herbivores are active and feeding on plankton is intense (Andriashev, 1968).

Whale migration routes are related to pack ice distribution. In the summer whales are found in open water, with the most southern portions of the stocks approaching the edge of the pack ice.



# The Southern Ocean

Boundary representation is not necessarily authoritative

### 4. Factors Affecting Primary Production

Antarctic waters are rich in nutrients. Circumpolar upwelling introduces nutrients into the euphotic zone throughout the year (Gordon, 1971). Water temperature is uniformly cold. The available light varies seasonally with the polar light regime and is closely correlated with primary production (El-Sayed and Mandelli, 1965).

Primary production is concentrated in the summer season, along the ice edge and in coastal regions (Balech, *et al*, 1968; El-Sayed, 1970). Because the early scientific investigations were concentrated in the most productive areas, a misleading picture of very high productivity for Antarctic waters was developed. Estimates have since been revised downward. On a yearly average basis over all southern ocean waters, including the less productive open ocean regions, total productivity is similar to that in other oceans (Holm-Hansen *et al*, 1977).

Food chains are shorter in the Antarctic than in other oceanic regions. Plants are consumed by krill (the dominant herbivores), which are in turn eaten by fish, birds, and mammals. But because food chains are shorter, a greater proportion of the productivity reaches the vertebrate trophic levels, and there is an unusually high density of birds and mammals in Antarctic waters.

Variation in sea ice cover affects light available to the water column because ice screens out light. Primary production in the winter is extremely low.

## B. Species in the Antarctic Marine Ecosystem

There is a distinct fauna south of the Antarctic Convergence. Phytoplankton consist primarily of diatoms south of the Convergence, but include a great many dinoflagellates north of it. Zooplankton species are different north and south of the Antarctic Convergence. *Euphausia superba* and *E. crystallorophias* are only found south of the Convergence, *E. superba* in oceanic regions and *E. crystallorophias* near the continent (Marr, 1962).

The term krill refers to the group of euphausiid crustaceans which are the food of large baleen whales. Species of krill are listed in Table 1. By far the most abundant of these species is *E. superba*.

Krill are omnivores, eating other zooplankton as well as phytoplankton. Krill are usually considered to be about half of the zooplankton population (Gulland, 1970). Other zooplankton include copepods, amphipods, and chaetognaths (Hopkins, 1971). Krill play a crucial role in the Antarctic marine food web because of their great abundance and because they are the main prey item for most of the predators in the ecosystem.

Squid are probably abundant in the Antarctic (Appendix F. BIOMASS, 1977). Squid eat krill and fish. Many fish eat krill. Birds, predominatly Adelie penguins, also eat krill (Prevost, in press). Other Antarctic birds include other penguins, petrels, albatrosses, and skuas.

Crabeater seals, a krill eating species, are the most abundant of Antarctic seals. Leopard, Ross, Weddell, elephant and fur seals are also present. The baleen whales which migrate into the Antarctic, fin, blue, sei, humpback, and minke whales, feed extensively on krill. Southern right whales are occasionally found south of the Convergence. The toothed whales, sperm and killer whales and some small cetaceans, are probably resident throughout the year.

Common and scientific names for species discussed in describing the Antarctic marine ecosystem are listed in Table 1.

At the present state of biological knowledge, standing stocks of resource populations other than whales in Antarctic waters are not well known. Abundance estimates for seals and penguins still vary considerably among investigators. The overall abundance of fish and cephalopods is virtually unknown. Abundance estimates and educated guesses on stock sizes for potential resource populations are discussed in Appendices E, F, G and H.

### 1. Krill

Krill have a circumpolar distribution, but are most abundant in the Weddell Sea, the East Wind Drift, the Weddell Drift and the South Georgia region (Nemoto, 1968; Marr, 1962; Mackintosh, 1973). Krill are found both under ice and in open waters.

E. superba collect in large amorphous swarms varying from a few to several hundred meters across. Swarms are apparently composed of individuals of a single age class. Swarms occur at varying depths from the water surface down to about 100 m. Not all krill are found in swarms. Even in regions of greatest abundance krill distribution is patchy

Table 1. Common and scientific names of some species occurring south of the Antarctic Convergence.

| | |
|---|---|
| Zooplankton | |
| Krill | *Euphausia superba* |
| | *E. crystallorophias* |
| | *E. triacantha* |
| | *E. frigida* |
| | *Thysanoessa macrura* |
| | *T. vicina* |
| Fish | |
| Antarctic cod | *Notothenia rossii* |
| | *N. gibberifrons* |
| | *N. coriiceps* |
| | *N. magellanica* |
| | *N. neglecta* |
| Antarctic tooth fish | *Dissostichus mawsoni* |
| Patagonian tooth fish | *D. eleginoides* |
| southern blue whiting or southern poutassou | *Micromesistius australis* |
| Antarctic silverfish | *Pleuragramma antarcticum* |
| icefish | *Channichthys rhinoceratus* |
| | *Chaenocephalus aceratus* |
| | *Champsocephalus gunnari* |
| | *Pseudochaenichthys georgianus* |

Table 1 (Continued)

| | |
|---|---|
| Squid | |
| giant squid | *Mesonychoteuthis hamiltoni* |
| other squid | *Moroteuthis ingens* |
| | *Conatus fabricii* |
| | *Pareledone* sp. |
| Birds | |
| Adelie penguin | *Pygoscelis adeliae* |
| Seals | |
| crabeater seal | *Lobodon carcinophagus* |
| leopard seal | *Hydrurga leptonyx* |
| Ross seal | *Omatophoca rossi* |
| Weddell seal | *Leptonychotes weddelli* |
| elephant seal | *Mirounga leonina* |
| fur seal | *Arctocephalus gazella* |
| Whales | |
| fin whale | *Balaenoptera physalus* |
| blue whale | *B. musculus* |
| sei whale | *B. borealis* |
| minke whale | *B. acutorostrata* |
| humpback whale | *Megaptera novaeangliae* |
| southern right whale | *Eubalaena australis* |
| sperm whale | *Physeter catodon* |
| killer whale | *Orcinus orca* |

(Appendix D, Everson, 1977; Tetra Tech, 1978). Because of its swarming habit, E. superba is the predominant krill species in the diets of mammals and penguins, and is the only krill species of commercial importance.

Estimates for krill standing stock vary almost tenfold, from about 180 to 1350 million metric tons (Appendix E, Green, 1977).

The circumpolar krill population may be a single breeding stock or may be composed of several separate stocks (Mackintosh, 1973; Makarov, 1974). More recent studies indicate that the breeding area has spread geographically since spawning females have been taken from the Scotia Sea, Bellingshausen Sea and Bransfield Straits. Spawning occurs at the surface from late November through late March. Early larvae are found in the East Wind Drift, the Bransfield Strait, the Scotia Sea, and the Weddell Drift (Everson, 1977; Tetra Tech, 1978). The Discovery expeditions collected very few eggs, and those only in the Scotia Sea (Marr, 1962).

Krill are long lived in comparison with zooplankton in warmer waters. However, there is still considerable doubt about total life span and age at which sexual maturity is attained. Krill may not breed until the beginning of their third or fourth summer and may breed for one or two seasons (Fraser, 1937; Bargmann, 1945; Ivanov, 1970; Everson, 1977).

Even though there is considerable scientific and commercial interest in krill, knowledge of physiology, breeding stocks, replacement rate and abundance is still incomplete.

### 2. Squid

It is possible that squid in the southern ocean are concentrated near the Antarctic Convergence (Appendix H, BIOMASS, 1977). However, squid serve as food for sperm whales, seals and fish whose distribution extends south toward the continent.

No direct abundance estimates for squid or other cephalopods are available for Antarctic waters, mainly due to inadequate sampling techniques (Everson, 1977).

There are squid fisheries in the waters near New Zealand and South America, but none in Antarctic waters. The "giant squid" Mesonychoteuthis hamiltoni may be of commercial potential (Everson, 1977).

Squid are major predators on krill. Larger individuals feed on fish or other squid.

The squid group, like the fish group, are krill predators and themselves serve as food for other predatory species as well as potentially harvestable resources. The presence of potentially harvestable populations are several trophic levels i.e., herbivores and primary and secondary carnivores, is a characteristic of the Antarctic ecosystem.

### 3. Fish

Fish stocks are thought to be low in the Antarctic (Gulland, 1970). In contrast to other oceans, there are not dense shoals of obligate pelagic fish in Antarctic waters. Pelagic fish present in the waters are Myctophidae, the Nototheniid genera Pleuragramma and Dissostichus, and the Gadoid genus Micromesistius. Although the Myctophidae may be abundant in the open ocean, they apparently do not form dense enough concentrations to support a fishery (Appendix H, Everson, 1977).

The Antarctic cod or Nototheniids are distributed in coastal areas around islands such as the Scotia Arc, Kerguelens, Crozet, Bouvet, and in the Magellanic and New Zealand regions. The latter may migrate south to the Ross and Scotia Seas in the summer, but most of the fish populations are probably resident in Antarctic waters. The southern blue whiting Micromesistius australis from the Magellanic and New Zealand regions does migrate into the Antarctic zone only during the summer to feed. The Antarctic tooth fish and Antarctic silverfish are found around the continent over continental shelves. Antarctic cod and some ice fish are being harvested commercially. Other fish species may constitute potentially harvestable resources.

### 4. Birds

The Antarctic Convergence is not a barrier for birds because of their mobility. However, breeding of penguins, albatrosses and petrels, cormorants, skuas, ducks, gulls and terns occurs along the coast of the Antarctic continent or on islands between 50°S and 65°S latitude. South Georgia and Kerguelen have the greatest diversity of breeding birds (Watson, et al, 1971; Everson, 1977).

Migratory birds are present in the Antarctic ecosystem, either south of the Convergence or on subantarctic islands, for only part of the year for feeding and breeding. The ecosystem provides habitat for such bird populations. When they move northward, they export some material from the Antarctic ecosystem.

Birds eat krill, squid, and fish. Adelie penguins are the most abundant species (measured by biomass) south of the Convergence. They consume very large amounts of krill in proportion to their body weight (Prevost and Sapin-Jaloustre, 1965; Prevost, in press). They are eaten by leopard seals and killer whales (Gilbert and Erickson, 1977).

### 5. Seals

The crabeater seals, whose population may be as high as 30 million individuals, are the most abundant seal in the Antarctic region and the most abundant seal in the world. They are residents of the pack ice region and feed mainly on krill. Other pack ice seals are the leopard and Ross seals. Pack ice seals breed in the pack ice region, usually south of 60°S latitude. Distribution of juveniles of these populations is unknown and they may occasionally range north of 60°S. Weddell seals inhabit coastal areas of fast ice. Ross and Weddell seals eat fish and squid as well as some krill. Leopard seals are predatory, eating mainly krill but also some fish, the young of other seal populations and occasionally penguins.

Elephant seals and fur seals breed on islands near the Convergence. The main population of the fur seal *Arctocephalus gazella* is at South Georgia. Other fur seals breed north of the Convergence. Elephant seals eat fish and squid; fur seals eat mainly krill. Elephant seals and fur seals are also resident in the Antarctic region (Erickson, *et al*, 1971; Erickson and Hofman, 1974; Appendix H, BIOMASS, 1977).

### 6. Whales

Whales are circumpolar in distribution. The baleen whales, or fin, blue, sei, humpback and minke whales, migrate into Antarctic waters during the austral summer to feed on krill. Southern right whales are occasionally found south of the Convergence. Baleen whales are found south of the Convergence from November through March. Individual animals average about four months feeding in the area. Whales feed in open water. The larger species and larger individuals within species penetrate further south, approaching the edge of the pack ice. While feeding intensively in Antarctic waters, baleen whales increase about 50% in weight during the summer season (Mackintosh and Brown, 1974; Laws, 1977a; Appendix H, BIOMASS, 1977).

Sperm whales, killer whales and some small cetaceans are probably resident in the Antarctic region. A third of the exploitable male sperm whale stock is assumed to feed south of the Convergence. Toothed whales eat fish and squid, possibly penguins and juvenile seals (Mackintosh and Brown, 1974; Laws, 1977a; Appendix H, BIOMASS, 1977).

Fin, blue, humpback and southern right whales are protected from harvest. The present population size of fin whales is about 20% of the original stock; blue whales are about 5%, and humpback whales about 3%. The sperm whale population is now about half of initial stock size and is now harvested. Sei whales which are harvested in some areas are presently slightly above half of initial population size. Minke whales, also harvested, are still as abundant as they were a century ago (Laws, 1977a).

As population size of baleen whales species has decreased, there have been changes in other population parameters. Sexual maturity is reached at a younger age now than when stocks were larger. The pregnancy rate is also increasing. These changes combine to increase the growth rate of the total population at low stock levels (Everson, 1977).

A growing population requires more food than a stable population of the same size. Thus it is possible that if whales were to expand populations to former levels, at some point their food requirements would be greater than the total food requirement of the original stock.

### C. Food Web

The importance of krill in the Antarctic marine ecosystem cannot be overemphasized. They are the most abundant zooplankton species. They are the main herbivore in the Antarctic marine ecosystem. Krill are the main food item for fish, squid, penguins, crabeater and leopard seals, and fin, blue, sei, humpback, and minke whales. Krill are present in the diet of other seals as well. Killer whales and sperm whales, in consuming fish and cephalopods and some seals, are only one step removed from krill in the food chain. A food web diagram for the Southern Ocean marine ecosystem is presented in Figure 2.

The dependence of many predators on one prey group, krill, is a very unusual ecological situation. The swarming habit of krill allows even very large predators to feed on them efficiently. Removal of krill from the ecosystem by commercial harvesting will compete directly with those predator populations feeding in the same geographic area and indirectly with other predators as overall abundance changes.

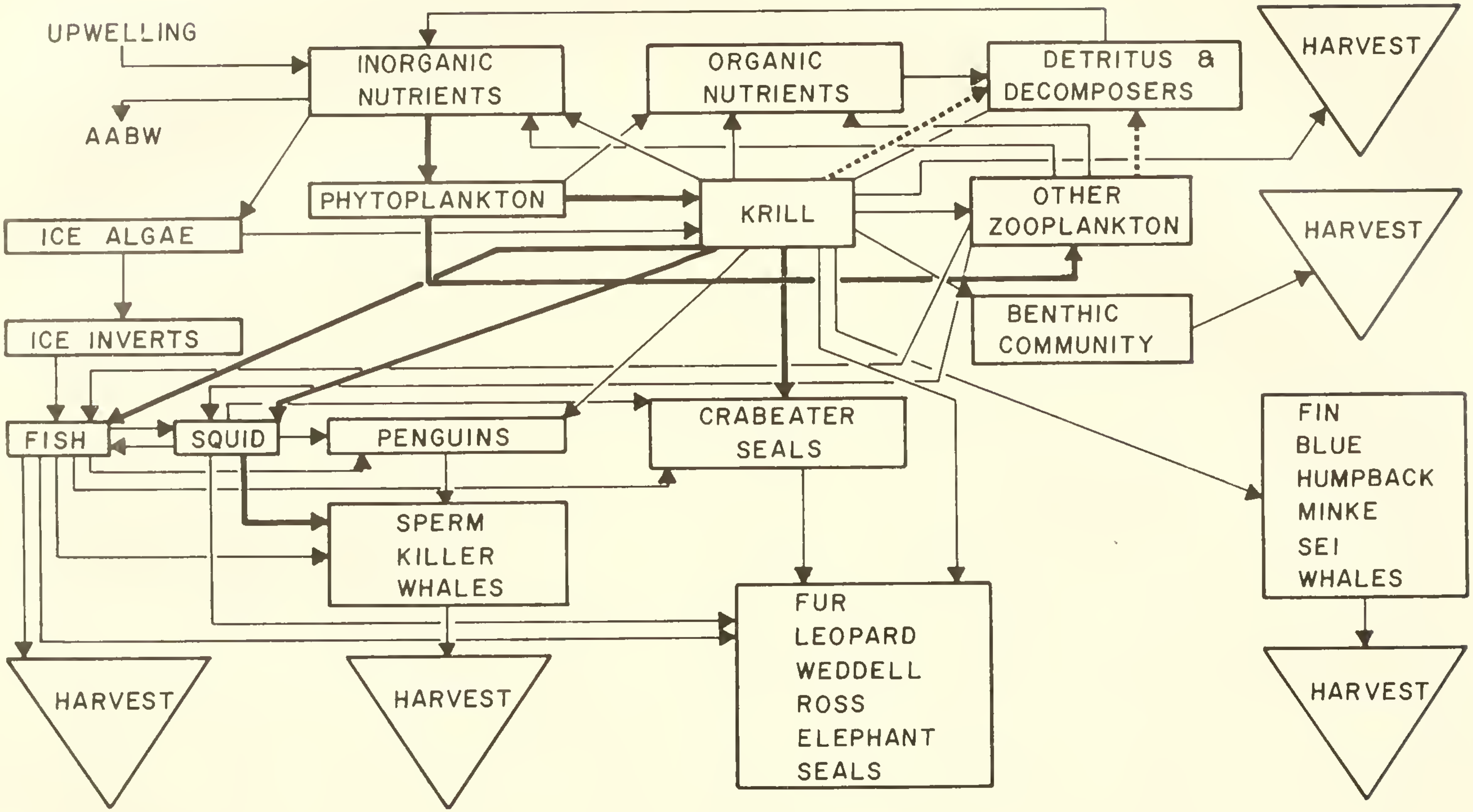


Figure 2. Food web relationships in the Antarctic marine ecosystem (Green, 1977).

If krill should be so depleted that some other group, such as copepods, became the most abundant zooplankton, a difference in overall food web structure for the ecosystem could result. Since copepod populations are dispersed, they would not support the same kind of large predators which krill can support by swarming. A hypothetical copepod-myctophid food chain might contain the same amount of carbon as the krill food web does now, but much more dispersed, so that the resources would not be as readily available, either to large predators or to commercial harvesting, as they are in the present system.

Crabeater seals are the biggest consumer of krill, taking about 106 million metric tons annually. Squid may take 100 million tons and fish 60 million tons although those estimates are not reliable, since fish and squid abundance estimates are speculative. Baleen whales consume about 43 million tons annually at present, birds about 14 million tons, and other seals about 3 million tons. Estimated annual total predation on krill is about 340 million tons. Krill harvested will come from the total now consumed by predators, not from some hypothetical part of the stock which is not utilized by predators (Appendix E, Green, 1977).

At initial stock levels, baleen whales consumed about 150 million tons more krill than do present populations (Laws, 1977a). The amount of krill consumed by seals, birds, fish, and squid a century ago is unknown. There is evidence that penguin and seal populations have increased in response to increasing krill availability as baleen whale populations decreased (Conroy, 1975; Laws, 1977b). From an ecological standpoint it is reasonable to expect that the Antarctic marine ecosystem has adjusted to the changing whale populations, even though the adjustment may not yet have been completed. It is also reasonable to expect that other populations in the ecosystem will respond to changes in krill availability as harvest levels increase.

### D. Areas of Special Biological Importance

The Scotia Sea is one of the regions of greatest krill abundance. Some fish species distributions are limited to the island groups of the Scotia Arc, Kerguelens, Crozet, Bouvet, South Georgia, the South Orkneys and the Antarctic peninsula.

Areas of feeding and breeding for fish, birds, and mammals should be considered for protected areas as should migratory pathways for whales and other migratory populations.

## E. History of Commercial Harvesting

Although the southern ocean is remote, it is not untouched by human activity. There is a long history of commercial harvesting there.

### 1. Whales

Whaling occurred in the Antarctic in the 19th and 20th centuries. Modern whaling with factory ships began in 1904. Species of commercial interest have been blue, fin, sei, minke, humpback and sperm whales. Populations of all of these except minke whales have been greatly reduced in the last 30 years. Whaling is now regulated under the International Whaling Convention. Fin, blue, humpback and southern right whales are protected from harvest. Sei, minke, and sperm whales are harvested (Everson, 1977; Mackintosh and Brown 1974; Laws, 1977a).

Blue whales are the largest of the whales, and consequently the most valuable to whalers and the earliest exploited. As blue whales declined, the smaller fin, sei, and minke whales were fished. Changes in the proportions of species caught have been a result of reduction in abundance from exploitation, not from changing preferences. Until the 1960's, the majority of world whaling occurred in the Antarctic. From 1945 to 1960 between 30,000 and 40,000 whales were caught in the Antarctic each year. Catches are now substantially reduced (Everson, 1977).

### 2. Seals

Sealing has also taken place in the Antarctic. In the last century the sealers contributed some scientific information about the region (Deacon, 1977). Except for a Norwegian exploratory expedition (Øritsland, 1970), pack ice seals have not been harvested for commercial purposes. Future harvesting of seals south of 60°S latitude will be regulated under the Convention for the Conservation of Antarctic Seals.

In the early 19th century, fur seals were harvested until populations declined. Then elephant seals were harvested but harvesting became unprofitable before populations were reduced to a critical level. After shore based whaling was established at South Georgia, sealing again became economically feasible and some overexploitation may have occurred prior to 1953. There is now no commercial harvest of fur or elephant seals (Everson, 1977). Harvesting is now regulated south of 60°S under the Convention for the Conservation of Antarctic Seals; no harvesting is taking place there at present.

### 3. Fish

Total reported catch in FAO statistical areas for the southern ocean (areas 48, 58, and 88) has been zero in recent years. However South Georgia and Kerguelen, known to be heavily fished, are included in reporting areas to the north (41 and 51). Only southern poutassou and Patagonian hake are reported as separate species in FAO Yearbook of Fishery Statistics.

It is probable that a large part of the catch of southern poutassou by the USSR in area 51 was taken in the Scotia Sea. Vessels of the USSR have fished near South Georgia and off Kerguelen (estimated catch 120,000 tons during the 1971-72 season). Principal species caught are *Notothenia rossi*, *N. squamifrons*, *Channichthys rhinoceratus*, and *Champsocephalus gunnari* (Appendix G. Everson, 1977).

Exploratory fishing has been done by West Germany, Japan, and Poland.

Catches in area 41 which includes South Georgia built rapidly to 400,000 tons and then declined rapidly to a few thousand tons. Decline in total catch was due in part to a great reduction in catch rate (Everson, 1977). Thus some fish stocks may already have been overexploited.

### 4. Krill

Because of their great abundance and because of the decline in their major predators, baleen whales, krill have been receiving increasing international interest as a potentially harvestable resource in recent years. Exploratory fishing for krill has been carried out by the USSR, Japan, Chile, West Germany, Poland, Norway, Taiwan, East Germany, Spain, and Korea (Appendix F, Everson, 1977; Tetra Tech, 1978).

The most recent catch statistics available for krill (1974) indicate a total catch of 20-40,000 tons. The estimate of an average take of 200,000 tons per season in recent years (McWhinnie, 1974) represents about 0.3 - 1% of estimated standing stock and about 0.3 - 0.8% of estimated annual production.

Krill harvesting research has been carried out in the summer months, December though March, and has been concentrated in the Weddell, Scotia, and Ross Seas, and the East Wind Drift. Harvestable densities have been encountered most frequently around South Georgia, the South Orkney Islands, the South Shetland Islands, and the South Sandwich Islands (Tetra Tech, 1978)

The only krill species of commercial interest at present is E. superba. Krill swarms are detected visually or acoustically. Detection and catching methods are now sufficient to harvest more krill than can be processed with available facilities. The main obstacles to expansion of the fishery are now product development and marketing. A total catch on the order of a million tons is possible in the immediate future. Once a fishery of this size is established, it would tend to expand rapidly. Both scientific information on krill stocks and information on the effect of harvesting on krill stocks and on krill predators are needed (Everson, 1977).

### 5. Penguins

Penguins have been harvested for their oil in the past. There is no present prospect for a commercial harvest of any Antarctic birds.

Historically, Antarctic fisheries have developed around krill predators, thus harvesting the krill production indirectly.

In the past commercial harvesting in Antarctic waters centered on seals and whales. Seals are no longer harvested, and the intensity of Antarctic whaling has been reduced in recent years. Commercial interest is now focused on fish and krill. Many nations are engaged in exploratory krill harvesting, and krill are expected to meet part of the increasing world demand for protein. Increasing fishing pressure on krill is anticipated in the next decade.

## F. Scientific Investigation

A great deal of scientific investigation has been carried out in Antarctic waters, mainly since the turn of the century, e.g., the Discovery expeditions. Scientific activity has intensified in the years since the ratification of the Antarctic Treaty in accordance with the objective of peaceful uses for the region.

Because the Antarctic marine region is relatively undisturbed in comparison with other ocean areas, and because it is a polar environment, it is the subject of much scientific interest. Studies have been carried out on the continent and ice shelves, in open waters, in the pack ice region and on the islands. All the original signatories of the Antarctic Treaty, Argentina, Australia, Belgium, Chile, France, Japan, New Zealand, Norway, South Africa, the USSR, the United Kingdom, and the United States have participated, as well as Poland and West Germany.

### G. Shipping Traffic

There is considerable shipping traffic in the Drake Passage by vessels too large to pass through the Panama Canal. Commercial shipping, including oil tankers, passes through that area, usually north of the Antarctic Convergence which lies about midway between South America and the Antarctic Peninsula in the Drake Passage. In addition scientific vessels and commercial fishing vessels are found throughout the southern ocean at various times of year. Relatively few vessels penetrate the pack ice zone.

### H. Ecosystem Responses to Disturbance

Even though the Antarctic marine ecosystem is relatively undisturbed in comparison with other oceanic regions, it is not a pristine area by any means. There has been harvesting of seals, whales, fish, krill, and penguins. Whaling has had the largest impact on stocks, with the populations of baleen whales drastically reduced from levels of a century ago.

Because baleen whales consume enormous quantities of krill during the summer season, the reduction in whale numbers has reduced the impact of whale predation on krill populations and has allowed more krill to become available to other predators. There is evidence that other populations within the ecosystem are adjusting to the changing abundance of whales. Penguin populations are increasing (Conroy, 1975) and there is evidence that seal populations are increasing also (Laws, 1977b). It is clear that the whale populations themselves are changing. Both population size and age at sexual maturity are different from original stock levels (Gambell, 1976; Laws, 1977a).

The Antarctic marine ecosystem as well as the Antarctic continent have been used as a scientific laboratory. Data on the biology of the Antarctic marine ecosystem come from both scientific and commercial investigations. Carefully controlled harvesting with good data reporting can create an opportunity for a controlled experiment on the Antarctic marine ecosystem which can provide a great deal of information about its biology.

### I. Potentially Harvestable Resources

An ecosystem viewpoint is a necessary perspective on the ecology and management of renewable resources in Antarctic waters. There are many potentially harvestable resources: fish, squid, seals, whales, krill and possibly birds. These populations are not independent but are closely related.

All of the others depend on krill as their main food supply. Krill are of central importance in the food web. Fluctuations in the size of krill populations will be reflected in the populations of its predators. In turn, fluctuations in the populations of predators, as exemplified by changes in whale populations, will affect the abundance of krill.

At the other end of the food chain, diatoms are abundant south of the Convergence and there is a limited amount of benthic macro-algae. There is no apparent interest in harvesting marine plants in the Antarctic at present.

An ecosystem perspective on Antarctic marine living resources is feasible. Interrelationships among species have been identified and can be taken into account. Quantitative information is still required for most stocks and many predation rates, but the structure of the ecosystem is known.

### J. No Native Peoples

There are no indigenous human populations residing or using resources south of the Antarctic Convergence.

## VI. ENVIRONMENTAL IMPACTS OF PROPOSED ACTION AND ALTERNATIVES

The proposed federal action represents one point on a continuum of management regimes for Antarctic living marine resources, from totally unregulated harvesting to a ban on all commercial harvesting. Similarly the impacts of each of the alternatives under consideration also fall on a continuum from greatest to least impact on the marine environment. Future activities associated with the development of non-living resources in Antarctic waters could affect living resources through modifications of the environment. For conservation of living resources, the activity of greatest concern in terms of environmental impact on the Antarctic marine ecosystem is commercial harvesting of renewable resources. Krill is the resource of most immediate interest, but there are other potentially harvestable resources as well: fish, squid, birds, and seals. Under different management regimes there would be different degrees of environmental impact.

There are three classes of impacts of commercial harvesting on the Antarctic marine ecosystem. The first and most significant are the impacts of harvesting on the populations of the renewable resources. The impacts are both direct, i.e. changes in abundance of any stock which is harvested, and indirect, i.e. changes in abundance of species which depend on the harvested stock for food. The second are the impacts of shipping traffic and harvesting operations on the local marine environment. The third is the impact of increased human activity on a relatively undisturbed marine ecosystem. The range of possible impacts of harvesting on stocks, on the marine environment, and on the southern ocean as a relatively undisturbed habitat will be discussed. Then the degrees of impact anticipated from the proposed federal action and the alternatives will be compared.

### A. Impacts of Commercial Harvesting

#### 1. Impacts Unaffected by Proposed Action

There are some environmental impacts of human activity in the Antarctic Ocean which will not be affected by the conclusion of the proposed conservation regime, specifically sealing and whaling. Sei whales, minke whales and sperm whales are harvested in the Antarctic while fin, blue, humpback and southern right whales are protected under the International Whaling Convention. Harvesting of crabeater, leopard, Ross and Weddell seals is regulated under the Convention for the Conservation of Antarctic Seals, which has recently entered into force. The Convention for Antarctic Seals applies only south of 60°S latitude. All breeding by pack ice and fast ice seals does occur south of 60°S although distributions of juveniles may occasionally extend north of that latitude during part of the year. Only those nations which are parties to the International Whaling Convention and the Convention for Conservation of Antarctic Seals are bound by the policies developed under those conventions. The possibility of unregulated harvesting by other nations does exist.

### 2. Direct Impacts on Exploited Stocks

The greatest environmental concerns over commercial harvesting in the Antarctic are the direct impacts of a harvest on the resource stocks themselves.

The Scotia Sea, Weddell Sea region is the only known area of krill (*E. superba*) spawning. At the same time it is one of the areas of greatest abundance of krill and is likely to be a region subject to intensive harvesting. Overexploitation of gravid individuals before reproduction occurs would jeopardize maintenance of a breeding stock. The same problem may occur in other geographic regions of krill abundance, but that cannot be determined until it is known whether krill are one or several breeding stocks. Geographic considerations will be important in management of krill harvesting.

Even though krill are very abundant, the possibility of their overexploitation is a real one. Krill abundance is estimated at 200 to 600 million tons in the summer. Since krill have a very long life span for zooplankton, their productivity may also be relatively low. The rate at which the krill population is replaced is not known at present. Therefore it is impossible to estimate sustainable yield with any accuracy. Nonetheless, expectations for krill harvesting are high. Present total world harvest of marine resources is around 70 million metric tons per year. Estimates for potential annual krill harvest range up to 150 million tons in the scientific literature (Everson, 1977) and up to 200 million tons in the popular press (Gwynne, 1977). After consideration of possible replacement rates, of increases in other krill predators with the decline of whales, and of the desirability of recovery of baleen whale populations, a sustainable annual harvest appears to be less than one-third of these estimates (Green, 1977). A potential for an enthusiastic unregulated harvest to overexploit the krill population is real.

Commercial exploitation of krill may have direct impacts on the stock other than a change in overall population size. Krill distribution patterns, productivity or secondary production rates, or behavior such as swarming patterns could also be affected.

In evaluating the potential impacts of various harvesting levels on krill populations, the different time scales of krill and predator populations must be taken into account. The life span of krill may be 2 to 4 years. The life span of krill predators such as a crabeater seal may be as much as 30 years. Since adjustments of predator populations to changes in krill abundance may take a long time, consumption by a large predator population which has not yet adjusted to a decreasing krill population must be taken into account in estimating impacts of harvesting on the krill population as a whole. Time lags in response vary for different predators, and are factors to be considered.

The present level of krill harvesting in the exploratory phase is roughly 20,000 - 40,000 tons per year, certainly too low for any direct impact on the krill stock. Practical considerations limit the total krill harvest now. Processing of krill must occur within a few hours of catching, and processing capacity is limited. Markets are not yet extensive. However, with improving ability to locate swarms, increasing vessel and processing capacities, and rising demand for protein, krill harvesting operations may soon be profitable. Considering the potential need to redeploy long distance fishing fleets as a consequence of extension of national fisheries limits (Eddie, 1977), the potential capacity to overexploit krill probably exists already.

Several fish species are already harvested in the Antarctic. Unregulated harvesting could lead rapidly to local overexploitation. The fishery techniques for fish harvesting are already well developed.

The southern blue whiting, Micromesistius australis, is a migratory fish. It is present in the Antarctic only during the summer season while it is feeding there. The rest of the year it is in the Magellanic and New Zealand regions. Harvesting of this species would not be regulated while it is outside the Antarctic ecosystem under the proposed conservation regime. The lack of regulation would be significant only in terms of the population of that one species. Should numbers of southern blue whiting decline, there would be at most a local impact on the rest of the Antarctic ecosystem. It could be replaced by other fish species in the diet of its predators.

There is no present commercial interest in birds or cephalopods in the Antarctic, although that cannot be ruled out as future possibility. However, no immediate direct impacts on populations of birds and squid are expected.

Harvesting of Antarctic seals under the Convention for the Conservation of Antarctic Seals will only be regulated south of 60°S latitude. Under the proposed conservation regime, pelagic sealing could also be regulated between 60°S and the Convergence. Elephant and fur seals on islands near the Convergence are not now harvested.

### 3. Indirect Impacts on Dependent Species

Concerns about the impacts of harvesting of one species on others which are dependent on it are most pertinent to krill as the target species. Fish, squid, birds, seals and whales depend on krill as a main food item, and are in turn potential resources.

Overexploitation of krill would be very dangerous to the Antarctic ecosystem. Consider the history of whaling. Most species of baleen whales have been reduced to roughly a tenth of their populations of a century ago. This change in whale numbers has caused some adjustments in other populations in the Antarctic ecosystem, but because whales are the end of a food chain, the internal structure of the ecosystem has remained essentially unchanged. However, should krill populations be reduced to a similar extent, enormous reductions in populations of fish, squid, seals and also whales would follow. Because of the crucial role of krill in the Antarctic marine food web, overexploitation would substantially alter the structure of the marine ecosystem and substantially damage its health.

Even without overexploitation, a large krill harvest would affect populations of krill predators. Krill removed by harvesting would come out of the total now consumed by predators. With a decrease in available food, predator populations in intensively harvested areas would drop.

Fin, blue, humpback and minke whales are presently protected from harvest under the International Whaling

Convention. An increase in the populations of these species is desired. Because the age of first reproduction for some of these species has decreased, a faster population recovery is possible. However, since baleen whales are entirely dependent on krill for food, a large krill harvest potentially would compete with whales for food supply. Probability of competition is increased since whale feeding and commercial harvesting would occur in the same geographic areas and at the same time of year. A reduction in food supply could cause a deterioration in physiological condition and in turn raise the age of first reproduction and slow the recovery rate of the populations. Further, a decrease in reproductive rates could contribute to a decrease in whale populations even without harvesting of whales.

Crabeater seals are also likely to be affected by a krill harvest because they are very abundant and because their diet is predominately krill. Because of their abundance, crabeater seals are also the seal most likely to be considered for commercial harvest. The impact of a krill harvest should be mitigated by geographic separation. Krill harvesting is most likely to occur in open waters and crabeater seals inhabit the pack ice region. However, juvenile seals, whose survival is critical to overall seal population dynamics, may feed in open water or near the edge of the pack ice, competing directly with the krill fishery.

Fish, birds and cephalopods which depend on krill as a major item of the food supply will be affected by a krill harvest. There is already evidence that bird populations are increasing due to increased krill abundance resulting from reduction in whale populations. Since harvesting will reduce krill availability, populations of predators are expected to decrease. Responses to a small krill harvest will be difficult to observe.

Ecosystem interactions are complex. The direct and indirect impacts of harvesting on Antarctic populations as discussed above reflect the dependence of population size on food supply through a variety of mechanisms. Because the Antarctic marine ecosystem is dynamic and has already been under stress through harvesting of various populations, especially baleen whales, other kinds of system responses are possible. A change in the structure or character of the ecosystem such as a shift to a copepod-myctophid dominated food chain is possible.

## 4. Local Impacts of Harvesting Operations

The mechanics of commercial harvesting of krill will have local impacts on the marine environments. Krill are caught by trawling. The processing of krill can be done on the trawler acting autonomously, or may be carried out by mother processing vessels at sea, or may use shore based factory facilities. Because krill spoil within several hours after catching, processing must be relatively rapid. Trawling vessels will have to operate close to factory facilities.

Most krill processing methods retain the soft flesh but discard the carapace of the organism. The hard parts of zooplankton are a normal component of detritus in sea water. In deep water, normal decomposition processes can handle krill parts which are dumped overboard. In shallow waters, such as around shore based processing facilities, discarded krill could accumulate, causing pollution problems or perhaps attracting scavenging birds.

Krill harvesting operations would also cause local pollution from ship bilges and garbage. Pollution problems would be most pronounced in a shore based factory facility with shallow surrounding water and would be intensified if a large support staff were living in the vicinity during the harvesting season.

At present, technological limitations on the rate of krill harvesting, limited market and availability of fishing vessels, have limited shipping traffic connected with krill harvesting. If krill harvesting is unregulated, shipping traffic will increase substantially within several decades, intensifying local pollution problems associated with harvesting and processing activities. Control on krill harvesting will incidentally regulate the level of shipping traffic.

## 5. Disturbance of the Marine Ecosystem

The Antarctic Treaty and Agreed Measures provide for peaceful uses of the Antarctic continent, which have included a great deal of scientific study. These agreements do not apply to surrounding ocean. Even so, there is recognition that the Antarctic marine ecosystem is important for scientific investigation, because it is a relatively undisturbed marine ecosystem and because there is intrinsic interest in polar oceanography.

The Antarctic ecosystem is not untouched by human activity. Some harvesting of fish and seals and extensive harvesting of whales have already occurred. With increasing commercial harvesting of krill and possibly other species, there will be increasing disturbance of the marine ecosystem and the nature of the system will be increasingly farther from a "natural state" for scientific study.

On the other hand, commercial data have provided information on stocks, abundance, reproductive and mortality rates and distributions, which otherwise would be unavailable. Data reported under the International Whaling Convention are an example. Such information cannot readily be collected on strictly scientific cruises. From a scientific standpoint, a carefully controlled harvest of various species with good monitoring and data reporting could provide an opportunity for a controlled experiment on the Antarctic marine ecosystem. Much could be learned about responses of the system to different levels of harvesting. In addition, such a controlled experiment could provide data which are needed for effective conservation of Antarctic living resources. More information is necessary to be able to manage for long term productivity of the ecosystem.

Some increase in the impact of human activities on the Antarctic marine environment appears to be inevitable. Commercial interest in krill harvesting is already developing, and harvesting levels are likely to increase as world protein demand rises. An increase in harvesting south of the Antarctic Convergence is expected even though the U.S. has no immediate plans to participate in it. Harvesting will increase whether a conservation regime is negotiated or not and regardless of whether the U.S. is a party to it. The purpose of a conservation regime and the motivation for U.S. participation in one is the mitigation of the impacts of uncontrolled harvesting.

### B. Environmental Impacts of Proposed Federal Action and Alternatives

The approaches to negotiating a conservation regime for Antarctic marine living resources, as indicated in the proposed federal action and alternatives to it, comprise six alternatives identified as (1) no action on a conservation regime, which implies no conservation measures, (2) individual national action on conservation policies and some coordination between these policies, (3) agreement on a regime for collection and transmittal of data at present, but postponing commitment to a conservation mechanism until later, (4) negotiation of a complete conservation regime providing for both data collection and an organization to establish conservation measures and regulate harvesting, (5) negotiation of a complete conservation regime, plus the establishment of quotas for harvesting of all resources or establishment of a moratorium on harvesting, and (6) prohibition of all harvesting in the Antarctic region.

The feasibility of negotiating each alternative, the ability to develop and enforce conservation measures, and level of harvesting activities anticipated under each alternative are presented in Table 2. The probabilities of overexploiting the various resource populations under each alternative are indicated in Table 3. Indirect impacts on stocks are compared in Table 4. Anticipated impacts on local marine environments and on the health of the ecosystem are indicated in Table 5. The effects of the alternative approaches on science are compared in Table 6.

### 1. Ban on Harvesting

The sixth alternative, prohibition of all harvesting, would imply no harvesting activities south of the Antarctic Convergence, if such a regime could be negotiated and enforced. This alternative would provide for the least impact on the Antarctic marine environment. It is the most favorable alternative for recovery of whale stocks. Small adjustments in other population sizes would be expected as whale populations increased.

A ban on harvesting would preclude the possibility of overexploitation of any stocks and would eliminate direct and indirect impacts of harvesting. Since seals and whales could be harvested under the International Whaling Convention and the Convention for Conservation of Antarctic Seals, small adjustments to other populations in response to sealing and whaling could be expected.

With the ban on harvesting, no commercial data would be available, thus eliminating a significant source of information on the stocks of some populations.

Even though this alternative represents the least environmental impact for the Antarctic marine ecosystem, achievement of a total ban on all harvesting is an unrealistic expectation. Such an agreement would not have the support of nations presently involved in exploratory krill harvesting, so that a total cessation of all harvesting could not be achieved.

### 2. No Action

The contrasting extreme of possible alternative action is no effort to negotiate a conservation regime and consequently no conservation measures for Antarctic waters. The consequences of this alternative are unrestricted and unregulated harvesting of all potentially commercial species. In time, technical and economic limitations on the harvesting of krill will be overcome. Intensive harvesting can be expected over the next several decades. An unregulated harvest will result in overexploitation of all harvested species.

This alternative represents the greatest impact on the stocks of renewable resources. Direct impacts on the separate stocks as they are harvested can be expected from overexploitation. In addition, indirect impacts on seals, whales, fish, birds and cephalopods from exploitation of krill would be maximum.

With overexploitation of krill or another species, the balance within the Antarctic system and the structure of trophic relationships can be upset, thus seriously damaging the health of the ecosystem. Unregulated harvesting will operate to maximize short term gains, thus potentially decreasing the overall productivity of the Antarctic ecosystem over the next century.

This alternative represents the greatest possibility of local pollution problems from harvesting activities.

In the absence of an agreement it is expected that commercial data will not be reported completely so that this source of information will be lost. This alternative would result in the greatest deviation from a natural or undisturbed state for the Antarctic ecosystem.

The actions of the U.S. and other Treaty nations at the Ninth Consultative Meeting indicate that they do not support this alternative (see resolution IX. 2. in Appendix A). However it is the default alternative should negotiations fail to establish a regime.

### 3. National Action

The second alternative is separate action on conservation of Antarctic living resources by nations interested in harvesting and some informal coordination between policies. Lacking consistent management objectives and a procedure for establishing and enforcing conservation

Table 2. Level of harvesting operations, feasibility of negotiation, and development and enforcement of conservation measures under the proposed action and alternatives.

| Alternatives | Activities Anticipated | Political feasibility | Develop conservation measures | Enforce conservation measures |
|---|---|---|---|---|
| No action; no conservation measures | Harvesting initially limited by technology, fleet size, and economics. Ships and shore facilities. As protein demand increases, all activities become more intensive. Unregulated, unrestricted and heavy harvesting of all species in 10-50 years ahead. (Assumes unregulated harvest will result in overexploitation.) | Recognized as undesirable by interested states. However, is default alternative. | No | No |
| National action and coordination | Harvesting initially limited by technology and economics. Could provide limited regulation and reporting as harvesting increases. However, national priorities would override ecosystem considerations - short term advantage would outweigh long term management. | Essentially voluntary and thus perhaps easy to achieve. Interested states desire more binding system. | No | No |

Table 2. (Continued)

| | | | | |
|---|---|---|---|---|
| Agreement on data now, commitment to mechanism later | Rely on technological, economic limitations for next 5-10 years. Risks overexploitation before regime can be negotiated. | Perhaps easy to achieve now, danger of vested economic interests hindering agreement on mechanism. | Not now; perhaps later. | Not now; perhaps later. |
| Complete conservation regime (Proposed federal action) | Rely on technology or agreement to keep harvests well below possibility of impact for immediate (5 year) future. Then total harvest for all species carefully regulated. Harvest activities, but no overexploitation; manage for long term productivity. | Appears an attainable objective, though requires careful negotiation. | Yes | Yes |
| Complete regime and establish quotas or moratorium on harvesting | Immediate harvests below impact level - either none or limited by technology. Danger of setting quotas wrong. | Moratorium won't get support of harvesting nations. Quotas would cause arguments, reduce likelihood of agreement. | Yes | Yes |
| Prohibit all harvesting | No harvesting activities. | No way to get agreement by all nations involved in resource activities. | Not needed | Not needed |

Table 3. Possibility of overexploitation of the various resource populations under the proposed federal action and alternatives.

| Alternatives | Krill | Fish, Birds, Cephalopods | Seals | Whales |
|---|---|---|---|---|
| No action; no conservation measures | small in immediate future; very likely within decades | presently low for birds and cephalopods because of lack of interest; likely for fish | Unlikely; regulated south of $60^{\circ}$S after Convention for Conservation of Antarctic Seals | overexploited in the past, now regulated by International Whaling Commission |
| National action and coordination | small in immediate future; very likely within decades | presently low for birds and cephalopods because of lack of interest; likely for fish | Unlikely; regulated south of $60^{\circ}$S after Convention for Conservation of Antarctic Seals | overexploited in the past, now regulated by International Whaling Commission |
| Agreement on data now, commitment to mechanism later | small in immediate future; possible before regime can be established | presently low for birds and cephalopods because of lack of interest; likely for fish | Unlikely; regulated south of $60^{\circ}$S after Convention for Conservation of Antarctic Seals | overexploited in the past, now regulated by International Whaling Commission |

Table 3. (Continued)

| | | | | |
|---|---|---|---|---|
| Complete conservation regime (Proposed federal action) | None in immediate future; minimal over long term | Some local fish populations already overexploited; otherwise low for immediate future and long term | Unlikely; regulated south of $60^{\circ}S$ after Convention for Conservation of Antarctic Seals | overexploited in the past; now regulated by International Whaling Commission |
| Complete regime and establish quotas or moratorium on harvesting | None in immediate future; minimal over long term | Some local fish populations already overexploited; otherwise low for immediate future and long term | Unlikely; regulated south of $60^{\circ}S$ after Convention for Conservation of Antarctic Seals | overexploited in the past; now regulated by International Whaling Commission |
| Prohibit all harvesting | None | None | Unlikely; regulated south of $60^{\circ}S$ after Convention for Conservation of Antarctic Seals | overexploited in the past; now regulated by International Whaling Commission |

Table 4. Changes in abundance of potentially harvestable resources under proposed federal action and alternatives.

| Alternatives | Krill | Fish, Birds Cephalopods | Seals | Whales |
|---|---|---|---|---|
| No action; no conservation measures | small change at first; large reductions possible within decades | abundance will decrease as krill harvesting reduces food supply | abundance will decrease as krill harvesting reduces food supply | unlikely to recover to optimal population size; further reductions possible |
| National action and coordination | small change at first; large reductions possible within decades | abundance will decrease as krill harvesting reduces food supply | abundance will decrease as krill harvesting reduces food supply | unlikely to recover to optimal population size; further reductions possible |
| Agreement on data now, commitment to mechanism later | small change in immediate future; large local population reductions possible before regime can be established | abundance will decrease as krill harvesting reduces food supply | abundance will decrease as krill harvesting reduces food supply | unlikely to recover to optimal population size; further reductions possible |

Table 4. (Continued)

| | | | | |
|---|---|---|---|---|
| Complete conservation regime (Proposed federal action) | very small change in near future; some reduction as harvesting increases but less change than with uncontrolled harvest | abundance will decrease as krill harvesting reduces food availability, but much less change than with uncontrolled harvest | abundance will decrease as krill harvesting reduces food availability, but much less change than with uncontrolled harvest | probable maintenance of present populations; some recovery possible |
| Complete regime and establish quotas or moratorium on harvesting | very small change in near future; some reduction as harvesting increases but less change than with uncontrolled harvest | abundance will decrease as krill harvesting reduces food availability, but much less change than with uncontrolled harvest | abundance will decrease as krill harvesting reduces food availability, but much less change than with uncontrolled harvest | probable maintenance of present populations; some recovery possible |
| Prohibit all harvesting | some adjustment to increasing whale abundance but probably not observable | some populations may decrease in response to increasing whale numbers | some populations may decrease in response to increasing whale numbers | most likely to recover to optimal population levels |

Table 5. Impacts on the marine environment and the health and productivity of the ecosystem under the proposed action and alternatives.

| Alternatives | Ensure harvest of one species doesn't harm others | Maintain long term productivity of whole system | Maintain health, preserve structure of ecosystem | Ship/shore factory impacts |
|---|---|---|---|---|
| No action; no conservation measures | Eventual overexploitation of krill will reduce all other resource populations | Very unlikely. Maximizing short term yields will eventually reduce overall productivity. | Overexploitation of krill can radically change structure of system. Overharvesting of other species can upset balance. | Low now; increasing w/o regulation. Shore bases likely locally adverse. |
| National action and coordination | Probable eventual overexploitation of krill will affect other resource populations. | Unlikely. Maximizing short term yields will eventually reduce overall productivity. | Overexploitation of krill can radically change structure of system. Overharvesting of other species can upset balance. | Low now; increasing w/o regulation. Shore bases likely locally adverse. |
| Agreement on data now, commitment to mechanism later | Possible overexploitation now; no provision for protecting all species. | Possible interim overharvesting of krill can reduce long term productivity. | Possible interim overexploitation of some species will cause readjustments in other population sizes. | Low now; possible increase to adverse levels. |

Table 5. (Continued)

| | | | | |
|---|---|---|---|---|
| Complete conservation regime (Proposed federal action) | Management of all species accounting for relationships to prevent reducing a population by overharvesting its food supply. | Regulate harvesting to maintain long term productivity. | Maintaining healthy system is realizable management objective. | Low now; increasing but regulated. Limited proportional to limited harvest. |
| Complete regime and establish quotas or moratorium on harvesting | Management of all species accounting for relationships to prevent reducing a population by overharvesting its food supply. | Regulate harvesting to maintain long term productivity. | Maintaining healthy system is realizable management objective. | Low now; increasing but regulated. Limited proportional to limited harvest. |
| Prohibit all harvesting | No harvesting implies no indirect impacts. | With only regulated harvesting whales & possibly seals, overall system productivity should remain essentially unchanged. | Except for whales and possibly seals, system left undisturbed will remain healthy. Other population sizes will change in response to seal and whale population changes. | None |

Table 6. Impacts of proposed federal action and alternatives on collection of scientific data and on the relatively undisturbed ecosystem.

| Alternatives | Basic Scientific Data | Commercial Data | Disturbance of system | Antarctic ecosystem as laboratory |
|---|---|---|---|---|
| No action; no conservation measures | No monitoring of stocks | None reported | Maximum | Farthest from undisturbed state, least useful for study of pristine ecosystem. |
| National action and coordination | No monitoring of stocks required | Catch data possibly reported | Maximum | Farthest from undisturbed state, least useful for study of pristine ecosystem. |
| Agreement on data now, commitment to mechanism later | Reported if collected | Catch data reported | Small in immediate future, possibly great disturbance later. | Increasing and potentially uncontrolled changes from present condition; study of a system under stress, later possibility of recovery. |

Table 6. (Continued)

| | | | | |
|---|---|---|---|---|
| Complete conservation regime (Proposed federal action) | Some monitoring required; scientific investigation encouraged. | Catch reported and analyzed | No additional or large impacts soon; some disturbance but maintenance of balance between populations under regulated harvesting. | Increasing but regulated harvest is opportunity for a controlled experiment; not a study of a pristine ecosystem. |
| Complete regime and establish quotas or moratorium on harvesting | Some monitoring required; scientific investigation encouraged. | Catch reported and analyzed | No additional or large impacts soon; some disturbance but maintenance of balance between populations under regulated harvesting. | Increasing but regulated harvest is opportunity for a controlled experiment; not a study of a pristine ecosystem. |
| Prohibit all harvesting | Not directly supported by conservation. | None available; precludes some information on stocks. | Minimum; only whale and possibly seal populations affected. | Minimal new disturbance, so closest to "natural" state but not a pristine system. |

measures, harvesting would be largely unregulated under such a system even though commercial catch data could be reported.

Fish harvesting would remain unregulated. Krill harvesting would be confined to low levels for the next several years by technical and economic limitations. However, as these are overcome, harvesting intensity would increase and emphasis would be on maximizing short term yields rather than protecting long term productivity of the system. Under such a regime, changes in populations of resource species would initially be small, but later increase in direct relationship to increased harvesting. Indirect impacts on species dependent on target stocks would be very likely within several decades.

Without a whole ecosystem perspective for management of harvesting, the health and long term productivity of the ecosystem would be endangered. This alternative represents almost as much negative environmental impact as does the alternative of no action regarding conservation measures.

Separate national policies and informal agreements between nations would be easier to reach than will be agreement on the proposed conservation regime. However, the Antarctic Treaty nations have endorsed establishment of a conservation regime (see Appendix A).

### 4. Data Reporting now, Conservation Measures Later

The establishment of a mechanism for recording and reporting commercial and scientific data now, with a commitment to establish conservation measures later, is the third alternative. The environmental impact of this alternative would depend on the time required for eventual negotiation of a conservation regime. In the event of establishment of vested economic interests in Antarctic resources before a regime could be established, the negotiation problems would be greatly increased and establishment of a conservation regime could be delayed by many years.

Present levels of harvesting for krill are limited by technical and economic considerations. There is no immediate interest in cephalopods and birds. Immediate impacts on the ecosystem would be small, with the exception of some fish which may already be overexploited. However, it is possible that overexploitation of some stocks could occur in the interval before a conservation regime could be negotiated. Overharvesting would reduce the long term potential productivity of the ecosystem.

Indirect impacts on the ecosystem would be expected to increase with time as harvesting levels increased. If stocks were damaged before the conservation regime could be established, recovery might be effected by selective conservation measures afterwards. However, the example of whaling has demonstrated that recovery can be a slow process. Proper management from the beginning is preferable.

### 5. Complete Conservation Regime (Proposed Federal Action)

The fourth alternative, and that which incorporates the proposed federal action, is that of establishment of a complete conservation regime. The regime would provide a mechanism for determining and enforcing necessary conservation measures. The objectives of the regime include prevention of overexploitation of any Antarctic resource, maintaining the health of the Antarctic ecosystem, ensuring that any harvesting of one species does not adversely affect related species, and maintaining long term productivity of the entire system.

Some changes in the Antarctic ecosystem would be expected as harvesting increased under a conservation regime, but the anticipated changes are much less than those expected with uncontrolled harvesting. Maintaining the health of the ecosystem and retaining long term productivity would be possible under this alternative. Although some disturbance of the ecosystem would occur, maintenance of balance between populations would be possible with carefully regulated harvesting.

The chance of overexploitation of any stock or damaging of a resource population by reduction of its food supply is minimized under this alternative. Recovery of whale populations would be possible.

Because the potential for overharvesting krill probably exists now, some form of limitation of harvesting during the interim period between negotiation and ratification of the proposed regime is desirable to prevent damage to the Antarctic ecosystem before the regime is operating.

Both scientific and commercial data would be reported and scientific investigations encouraged under the regime. From a scientific standpoint, the opportunity for observing and studying a relatively undisturbed system would be decreased as harvesting levels increased.

However, a carefully controlled catch with data collected and reported would provide an opportunity for a controlled experiment on the ecosystem which could promote considerable advances in scientific understanding. Such data are necessary for establishing appropriate conservation measures to meet the objectives of the proposed regime.

Although a great deal of information is available on Antarctic living resources, there are still considerable uncertainties in estimates of both standing stocks and turnover rates or productivity of the various resource populations. Conservation measures developed under the proposed conservation regime should take these uncertainties in information into account and minimize risks to the environment through cautious development of fisheries. Any harvesting should be coupled with collection and analysis of basic biological information as well as catch data on target and associated species.

To be completely effective, such a regime should include all nations which are engaged in harvesting in Antarctic waters.

The U.S. is not presently involved in commercial harvesting in Antarctic waters, and there appears no immediate prospect of a U.S. fishery there. However, the U.S. is a leader in research concerning the Antarctic marine environment, and has important interests in the conservation of Antarctic marine living resources. These interests include the rational development of new sources of protein in prevention of international conflict over Antarctica as well as a commitment to maintaining the Antarctic environment. In the face of possible large scale harvesting by other nations in the near future, the proposed conservation regime offers the best alternative for implementing these U.S. interests.

### 6. Conservation Regime with Specific Conservation Measures or Interim Harvesting Moratorium

The fifth alternative, and the last one to be discussed, is similar to the fourth alternative favored by the U.S. because it also entails negotiation of a complete conservation regime. It differs from the proposed action in that the agreement itself would either set harvesting quotas for all species or establish an interim moratorium on all harvesting. The environmental impacts of this alternative are very similar to those of the fourth alternative.

The main potential adverse impact lies in setting quotas too high for some species out of present ignorance of the abundance and population dynamics of some stocks. If quotas were set too high, then overexploitation and consequent adjustment of other populations within the system would become possible.

This alternative is a much more difficult one to negotiate than the fourth because of the necessity of either agreeing on a moratorium or establishing harvesting quotas. A moratorium would prevent the gathering of some commercial data which could be useful in establishing eventual conservation measures.

## VII. SHORT VS. LONG TERM PRODUCTIVITY

The Antarctic marine ecosystem is rich in renewable resources and is an important potential source of protein In addition, the system is useful for scientific study and other peaceful activities. The ecosystem as a whole is vulnerable to bad management and overexploitation of stocks. Only seals, whales, and some fish populations have yet been harvested extensively. The remaining fish, squid, birds, and krill stocks have large standing stocks which could be easily over harvested by maximizing short term gains and harvesting at standing stock levels rather than at sustainable yield levels. Unregulated harvesting would lead to overexploitation and consequent reduction of yield. The proposed conservation regime and the U.S. position with regard to the negotiations seek to maintain the long term productivity of the ecosystem. Negotiation of a complete conservation regime is the best method of ensuring long term productivity of the Antarctic marine ecosystem.

## VIII. UNAVOIDABLE ADVERSE IMPACTS

As commercial harvesting of krill and other species increases, responses of the rest of the system to decreasing food supply can be expected. With an increasing krill harvest, populations of krill predators, fish, birds, cephalopods, seals, and whales can be expected to decrease. Reductions will be most notable in local regions where krill harvesting is the most intense.

Recovery of protected whale species to former population levels may be slowed or prevented by intensive harvesting of krill.

Harvesting represents increased human impact on a relatively undisturbed ecosystem which is valuable for scientific study.

Changes will occur whether or not a conservation regime is negotiated. However, the establishment of a regime as set forth in the proposed federal action would have as a basic objective the minimization of adverse impacts of anticipated commercial harvesting on the Antarctic marine ecosystem.

## IX. COMMITMENT OF RESOURCES

The United States presently has no commercial fishery interest in Antarctic waters. No commitment of personnel or vessels for commercial harvesting is anticipated in the near future. However, the possibility of future harvesting is retained.

Pursuant to a negotiated regime, the United States expects to support the required scientific research which will aid in the establishment of conservation policies. The United States will continue to fund scientific research in the Antarctic.

The United States would expect to contribute a share of the cost of running the regulatory organization set up by the negotiated conservation regime.

In the interim period before conservation regulations can be established and enforced, some portion of fish and krill populations will be removed from the ecosystem. Limitations on harvesting ability, either technical and economic considerations or some agreement for controls on interim harvesting, will ensure that the impact of the interim harvesting on the Antarctic ecosystem is minimal. In addition, the resources which will be removed are renewable, and so will not constitute a permanent loss to the system.

Resources which will continually be removed from the Antarctic ecosystem as regulated by the established conservation machinery are renewable. The conservation regime will minimize the adverse impacts of harvesting.

## X. CONCLUSIONS

A total ban on harvesting of all Antarctic living resources could not be negotiated or enforced. Therefore, assuming that commercial harvesting in Antarctic waters will increase in the future, the United States seeks to minimize the adverse environmental impacts of such harvesting through negotiation of a conservation regime. The proposed federal action provides for the establishment of a complete conservation regime now, before vested economic interests in Antarctic resources are established. A conservation regime will be most effective in minimizing adverse impacts if management can begin before any stocks have been overexploited. The regime should include provisions for determining and enforcing conservation measures. Establishment of a conservation regime is the best means of ensuring the long term productivity of the renewable resources in the Antarctic marine ecosystem.

## XI. CONSULTATION AND COOPERATION WITH OTHERS

Preparation of the proposal of a regime for conservation of Antarctic marine living resources and the Department of State's environmental impact statement on the regime has involved extensive and valuable consultation and cooperation within the United States Government, with the U.S. Congress and public and with other nations.

Immediately after the Government of Norway proposed that the Antarctic Treaty parties consider the conservation of Antarctic living marine resources at the Eighth Antarctic Treaty Party Consultative meeting in June, 1975 at Oslo, the United States delegation offered to host an international scientific conference on the living resources of the Southern Ocean. The purpose of the conference was to provide nations with the opportunity to review the existing knowledge of the living resources of the Southern Oceansand to develop a proposal for future cooperative studies in the area. The conference was later held in August, 1976 in Woods Hole, Mass. It brought together 59 scientists from 14 countries, including the U.S., working within the Scientific Committee for Antarctic Research (SCAR), and laid the basis for a needed understanding of the structure and dynamic function of the Antarctic marine ecosystems as a basis for the future management of potential living resources there. It provided additional scientific information on the international level for the later decision of the Antarctic Treaty parties in their Ninth Consultative meeting at London in December 1977 to elaborate a regime to conserve living resources in waters surrounding the Antarctic continent. The report of the conference is contained in Appendix H of the Final EIS.

During the development of the regime proposal, the appropriate committees and members of the U.S. Congress have been closely consulted. On September 12, 1977 Acting Assistant Secretary of State for Oceans and International Environmental and Scientific Affairs Robert C. Brewster briefed the House of Representatives Subcommittee on Fisheries, Wildlife Conservation and the Environment of the Merchant Marine and Fisheries Committee and the Environment and Atmosphere Subcommittee of the House Science and Technology Committee on the proposed regime during testimony on H.R. 7749. Acting Assistant Secretary Brewster updated this information before the Subcommittee on Fisheries, Wildlife Conservation and the Environment on October 13, 1977. In testimony on February 6, 1978 Assistant Secretary Patsy T. Mink and Ambassador Brewster, along with other

Government and private witnesses, informed the Senate Arms Control, Oceans and International Environment Subcommittee of the Senate Foreign Relations Committee on the development of policy with respect to Antarctic resources exploitation, including the negotiations for the Antarctic marine living resources regime. On May 2, 1978 Acting Assistant Secretary Brewster updated information on planning and developments for the proposed conservation regime in testimony on H.R. 10905 before the House Subcommittee on Fisheries, Wildlife Conservation and Environment.

Department of State officials held a formal public meeting in the Department in Washington, D.C. on December 20, 1978. At the meeting individuals and representatives of non-governmental organizations gave their views on a possible conservation regime (Appendix B).

Public participation and views were solicited again on February 10 when the Department held a public meeting to receive oral comments on the "Draft Environmental Impact Statement on the Negotiation of a Regime for Conservation of Antarctic Marine Living Resources," which the Department had published and distributed to Federal agencies and the public on February 1. Comments on the Draft EIS were requested by March 20; the comment period was later extended to April 14 to allow additional public comment.

The Draft EIS was distributed to all Federal agencies with interests in the Antarctic, including all members of the U.S. Government's Interagency Antarctic Policy Group. It was also sent to non-governmental organizations and individuals who were known to be interested in the proposed regime or who requested copies of the Draft EIS. A list of the agencies and organizations is contained in the summary section of the Draft EIS. The draft statement was distributed as well to principal involved U.S. Senators and Congressmen and to U.S. Congressional Committees, including the Subcommittee on Arms Control, Oceans and International Environment of the Senate Foreign Relations Committee, the National Oceans Policy Study of the Senate Commerce Committee, the Subcommittee on Environmental Pollution of the Senate Environment and Public Works Committee, the Subcommittee on International Security and Scientific Affairs of the House International Relations Committee, the Subcommittee of Fisheries and Wildlife and International Environment of the House Merchant Marine and Fisheries Committee, and the Subcommittee on Environment and the Atmosphere of the House Committee on Science and Technology.

To obtain additional benefit of the views of the public and Congress the U.S. delegation to the international negotiating session on the proposed regime at the Special Consultative Meeting in February 1978 at Canberra, Australia contained three public members and a Congressional staff representative.

In the meantime, comments on the Draft EIS were carefully reviewed by appropriate Departmental officials. They are commented upon in Appendix J of the Final EIS and appropriate changes and amendments have been made in the Final EIS. The Federal agency, private organization and individual comments on the Draft EIS are published in full in Appendix I of the Final EIS.

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# APPENDIX A

## The Ninth Antarctic Treaty Consultative Meeting

ANTARCTIC TREATY
NINTH CONSULTATIVE MEETING

ДОГОВОР ОБ АНТАРКТИКЕ
ДЕВЯТОЕ КОНСУЛЬТАТИВНОЕ СОВЕЩАНИЕ

TRAITÉ SUR L'ANTARCTIQUE
NEUVIÈME RÉUNION CONSULTATIVE

TRATADO ANTARTICO
NOVENA REUNION CONSULTIVA

LONDON

ANT/IX/83 (Rev 3)
Date: 8 December 1977

# REPORT OF THE NINTH ANTARCTIC TREATY CONSULTATIVE MEETING

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II. Recommendations adopted at the Ninth Antarctic Treaty Consultative Meeting

III. Annexes

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  6. Documents on Tourism submitted to the Ninth Consultative Meeting and referred to the Tenth Consultative Meeting for further consideration.

## I

## FINAL REPORT OF THE NINTH ANTARCTIC TREATY CONSULTATIVE MEETING

1. In accordance with the provisions of Article IX of the Antarctic Treaty, representatives of the Consultative Parties (Argentina, Australia, Belgium, Chile, France, Japan, New Zealand, Norway, Poland, the Republic of South Africa, the Union of Soviet Socialist Republics, the United Kingdom of Great Britain and Northern Ireland and the United States of America) met in London from 19 September to 7 October 1977 to consult together and consider measures which might be taken to further the principles and purposes of the Treaty and, where appropriate, make recommendations to their Governments.

2. Mr George Hall, Representative of the United Kingdom, acted as Temporary Chairman of the Meeting pending the election of a Chairman.

3. The Meeting was formally opened by Mr Ted Rowlands, MP, Minister of State for Foreign and Commonwealth Affairs of the United Kingdom.

4. Mr Hall was then elected Chairman, Mr John Smallwood of the FCO was appointed Secretary-General and Mr Ian Duncan of the FCO was appointed Assistant Secretary General.

5. The Opening Session was held in public. Opening statements were made by the Heads of Delegations (Annex 1).

6. The Meeting adopted the following Agenda:

1. Opening of meeting
2. Election of officers
3. Opening statements
4. Adoption of agenda
5. Antarctic resources - the question of mineral exploration and exploitation (Recommendation VIII-14, operative paragraph 4)
6. Antarctic marine living resources (Recommendation VIII-10, operative paragraph 5)
7. Improvement of telecommunications in Antarctica and of the collection and distribution of meteorological data
8. Effects of tourists and non governmental expeditions in the Antarctic Treaty Area. Completion of Annexes A and B to Recommendation VIII-9
9. Co-operation in transport (Recommendation VIII-7)
10. Man's impact on the Antarctic environment
11. Activities in the Antarctic of states that are not Contracting Parties
12. Documents of the Consultative Meetings
13. Review of conservation measures and Sites of Special Scientific Interest
14. Date and place of next Consultative Meeting
15. Any other business
16. Adoption of Final Report
17. Closing of meeting

7. The Meeting considered in Plenary Session all the items on the Agenda and appointed four main Working Groups, as well as Working Committees, comprising members of all those Delegations wishing to participate, to assist it in reaching conclusions on certain items. A Working Group of Experts on Exploration and Exploitation of Antarctic Minerals was chaired by Dr Martin Holdgate, Alternate Representative of the United Kingdom; a Working Group on Antarctic Marine Living Resources was chaired by HE Mr John McArthur, Representative of New Zealand; a Working Group on Antarctic Telecommunications was chaired by HE Mr Stephane Hessel, Representative of France; a Working Group on the Legal and Political Aspects of Mineral Resources, was chaired by HE Mr Juan Carlos Beltramino, Representative of Argentina. HE Mr Keith Brennan, Representative of Australia, chaired a Working Committee on Marine Living Resources; Mr Jorge Berguno, Deputy Representative of Chile, chaired a Working Committee on Tourism; and HE Mr Stephane Hessel, Representative of France, chaired a Working Committee on the Legal and Political Aspects of Mineral Resources.

8. The Meeting adopted unanimously the following Recommendations, which are set forth in this Report:

IX-1 : Antarctic mineral resources
IX-2 : Antarctic marine living resources
IX-3 : Improvement of telecommunications in the Antarctic
IX-4 : Co-operation in transport
IX-5 : Man's impact on the Antarctic environment
IX-6 : Oil contamination of the Antarctic marine environment

9. Mineral resources

The Working Group of Experts on Exploration and Exploitation of Antarctic Minerals met from 20 September until 29 September and had before it the report of the Scientific Committee on Antarctic Research (SCAR) Group of Specialists entitled A preliminary Assessment of the Environmental Impact of Mineral Exploration/Exploitation in Antarctica (EAMREA). Its Report was submitted to Plenary by Dr Holdgate on 29 September. The Report was welcomed by Representatives who decided that it should be annexed to the Final Report of this meeting, together with a list of the experts who participated in the discussions (Annex 5).

The Working Group on the Legal and Political Aspects of Mineral Resources, and its Working Committee, met from 29 September-6 October. Its Report, which included a draft Recommendation, was submitted to Plenary on 7 October.

10. Living resources

The Working Group on Marine Living Resources, and its Working Committee, met from 21 September-6 October. Its Report, which included a draft Recommendation, was submitted to Plenary on 7 October.

The Working Group agreed to include in its Report the understanding of the Group that the word "conservation" as used in the draft Recommendation includes rational use, in the sense that harvesting would not be prohibited, but the regime would exclude catch allocation and other economic regulation of harvesting. It was similarly the understanding of the Group that the word "resources" was not limited to commercially exploitable species.

In connection with the Special Consultative Meeting referred to in paragraph 2, Part III of Recommendation IX-2, the Representatives welcomed the invitation issued by the Government of Australia to hold the meeting in Canberra from 27 February to 16 March 1978.

11. Telecommunications

The Working Group met on 30 September and 4 October. Its Report, which included a draft Recommendation, was submitted to Plenary on 6 October.

12. Tourism

A draft statement of accepted practices and the relevant provisions of the Antarctic Treaty, together with a draft containing practical guidance for visitors to the Antarctic, were considered for inclusion in Annex A of Recommendation VIII-9 but, owing to lack of time for full discussion, the matter was referred to the Tenth Consultative Meeting. The drafts are reproduced at Annex 6.

No action was taken to list or define areas of Special Tourist Interest for inclusion in Annex B of Recommendation VIII-9.

## 13. Man's impact on the Antarctic environment

With the items on the agenda concerning Antarctic resources particularly in mind, the Representatives discussed the question of man's impact on the Antarctic environment. They recalled the numerous steps already taken by Consultative Parties designed to protect the Antarctic environment from unnecessary interference, including:

(i) The designation by the Consultative Parties of the Treaty Area as a Special Conservation Area and the adoption of the "Agreed Measures for the Conservation of the Antarctic Fauna and Flora".

(ii) The designation of "Specially Protected Areas" to preserve their unique ecological system and "Sites of Special Scientific Interest" to enable scientific investigations to be carried out at those sites without interference.

(iii) The negotiation of the Convention for the Conservation of Antarctic Seals (London 1972).

(iv) The adoption of measures to preserve and protect from damage historic monuments situated in the Antarctic Treaty Area.

(v) The adoption of a Code of Conduct to be observed at their stations and by their expeditions within the Antarctic Treaty Area.

They also recall that in close co-operation with the Scientific Committee on Antarctic Research (SCAR) of the International Council of Scientific Unions, and through SCAR with other appropriate international organisations concerned, they have developed plans for the comprehensive study of the Antarctic marine ecosystem considered as an integral part of the Antarctic environment and have sought to:

(a) identify the types and assess the extent of human interference which has occurred in the Treaty area as a result of man's activities;

(b) assess the possible impact on the environment of the Treaty Area and other dependent ecosystems if mineral exploration and/or exploitation were to occur there.

The Representatives, while considering the next steps to be taken with regard to questions concerning Antarctic resources, decided to recommend that their Governments should reaffirm their commitment to environmental protection. Accordingly the Representatives drew up the statement contained in Recommendation IX-5.

14. Activities in the Antarctic of other states

This question was widely discussed.

In connection with possible substantial or continuing activities in the Antarctic Treaty Area by States that are not Contracting Parties of the Treaty, the Representatives recalled their agreed view expressed in the Final Report of the Seventh Antarctic Treaty Consultative Meeting that it would be advisable for Governments to consult together as provided for by the Treaty and be ready to urge or invite as appropriate the State or States concerned to accede to the Treaty, pointing out the rights and benefits they would receive and also the responsibilities and obligations of Contracting Parties.

15. Information and documents of Consultative Meetings

The question of availability of information and documents to the public was discussed and it was generally agreed that there should be increased efforts to make both more available to the public.

16. Review of Conservation Measures and Sites of Special Scientific Interest

The attention of Representatives was drawn to two errors in Recommendations VIII-1 and VIII-4 respectively. The Representatives decided to correct the latitude shown on the map attached to Recommendation VIII-1 so as to read 66° 16' S. The Representatives decided to remove the discrepancy between the Management Plan for Site of Special Scientific Interest No 6 (attached to Recommendation VIII-4) and the attached map by substituting the word "three" for the word "four" in section (i) of the Management Plan.

The Meeting considered the question of the designation of Marine Sites of Special Scientific Interest and the opinion was expressed that SCAR should be invited to examine this matter. In this connection, Representatives noted that the Government of Chile intended to propose to SCAR, following agreed procedures, two Marine Sites of Special Scientific Interest.

The United States Delegation submitted the following information on its experience in Sites of Special Scientific Interest:

> Management plans for seven Sites of Special Scientific Interest (SSSI) were accepted as interim guidelines by Recommendation VIII-4 in 1975. The 1976-77 austral summer provided the first opportunity to incorporate these guidelines into Antarctic operating procedures.
>
> The existing seven SSSI expire June 30, 1981, which date is likely to occur before the eleventh Consultative Meeting.
>
> The US Antarctic Program controls visits to SSSI by a permit system and has found this to be an effective means of reducing harmful interference at SSSI 1, 2, 3 and 4 during the 1976-1977 operating season. The posting of information signs around SSSI has been a deterrent to unintended interference by tourists. During this initial year of operations, the US issued one permit for access to SSSI. One request for access to SSSI 3 was denied on grounds that the proposed purpose was in conflict with the Management Plan as set forth in Recommendation VIII-4.

## 17. Tenth Consultative Meeting

Representatives accepted with pleasure the invitation of the Representative of the United States to hold the Tenth Consultative Meeting in Washington, DC in 1979.

## 18. Other business

The United States Delegation submitted documents showing the status of approvals by Governments of Recommendations adopted at Consultative Meetings, as received and recorded by the United States Government as depositary Government for the Antarctic Treaty, up to and including 13 September 1977. The documents are reproduced at Annex 3.

During the course of the Ninth Consultative Meeting it was unanimously agreed that the greetings of all Representatives be conveyed to the Antarctic Stations of the Consultative Parties. The text is at Annex 4.

The Consultative Parties were agreed that in view of the number of important matters requiring continuing consideration it was desirable to meet on a more frequent basis than in the past. It was noted that the holding of Special Consultative Meetings for ad hoc purposes would be a response to this need; and it was agreed that the question of periodicity and nature of meetings within the Treaty framework should be included as an item on the agenda of the Tenth Consultative Meeting.

## II

## RECOMMENDATIONS ADOPTED AT THE NINTH ANTARCTIC TREATY CONSULTATIVE MEETING

### IX - 1

### ANTARCTIC MINERAL RESOURCES

The Representatives,

Recalling the provisions of the Antarctic Treaty, which establishes a regime for international cooperation in Antarctica, with the objective of ensuring that Antarctica should continue forever to be used exclusively for peaceful purposes and should not become the scene or object of international discord;

Bearing in mind the provisions of Article IV of the Treaty;

Convinced that the framework established by the Antarctic Treaty has proved effective in promoting international harmony in furtherance of the purposes and principles of the United Nations Charter, in ensuring the protection of the Antarctic environment, and on promoting freedom of scientific research in Antarctica;

Noting with thanks the Report of the Scientific Committee on Antarctic Research (SCAR) Group of Specialists entitled Preliminary Assessment of the Environmental Impact of Mineral Exploration/Exploitation in Antarctica (EAMREA);

Recognizing nevertheless that adequate scientific data concerning the harmful environmental effects of activities related to the exploration and exploitation of Antarctic mineral resources, should they occur, are not yet available;

Concerned that unregulated activities related to exploration and exploitation of mineral resources could adversely affect the unique environment of the Antarctic and other ecosystems dependent on the Antarctic environment;

Conscious that the Consultative Parties to the Antarctic Treaty in carrying out scientific research in the area have accumulated valuable experience and can substantially contribute to the protection of the environment and the rational use of Antarctic mineral resources, should exploration or exploitation thereof occur;

Aware of the special responsibilities of Consultative Parties to ensure that any activities in Antarctica, including commercial exploration and exploitation in the future, should they occur, should not become the cause of international discord, of danger to the unique Antarctic environment, of disruption to scientific investigation, or be otherwise contrary to the principles or purposes of the Antarctic Treaty;

Recommend to their Governments that:

1. They reaffirm the basic principles set forth in Recommendation VIII-14 of the Eighth Antarctic Treaty Consultative Meeting;
2. They take note with appreciation of the Report of the Group of Experts on Mineral Exploration and Exploitation annexed to the Report of the Ninth Consultative Meeting and make the best possible use of its conclusions and guidelines;
3. They continue to study the environmental implications of mineral resource activities in the Antarctic Treaty Area and hold at a time and place to be arranged through diplomatic channels a meeting of ecological, technological and other related experts, in accordance with Recommendation IV-24, with a view to developing scientific programmes aimed at:
   (i) improving predictions of the impact of possible technologies for mineral exploration and exploitation in the Antarctic, as outlined in Section IIB of the Report of the Group of Experts, and in Section 5 of the SCAR EAMREA Group Report;
   (ii) developing measures for the prevention of damage to the environment or for its rehabilitation, in accordance with Section IIC of the Report of the Group of Experts;
4. They endorse the following principles elaborated at the Special Preparatory Meeting held in Paris from 28 June to 10 July 1976:-
   (i) The Consultative Parties will continue to play an active and responsible role in dealing with the question of the mineral resources of Antarctica;
   (ii) the Antarctic Treaty must be maintained in its entirety;

(iii) protection of the unique Antarctic environment and of its dependent ecosystems should be a basic consideration;

(iv) the Consultative Parties, in dealing with the question of mineral resources in Antarctica, should not prejudice the interests of all mankind in Antarctica;

5. They note that the provisions of Article IV of the Antarctic Treaty shall not be affected by the regime. It should ensure that the principles embodied in Article IV of the Antarctic Treaty are safeguarded in application to the area covered by the Antarctic Treaty;

6. They study the content of a future regime based on the principles contained in paragraphs 4 and 5 and on such further principles, rules and arrangements as may be agreed, taking full account of all proposals submitted to the IXth Consultative Meeting;

7. The subject "Antarctic Resources - The Question of Mineral Exploration and Exploitation" be the subject of intensified consultation among them and they urge the host Government of the Tenth Consultative Meeting to convene a meeting to consider legal and political aspects of mineral resource issues; this meeting to report to the Tenth Consultative Meeting on the results of its work;

8. They urge their nationals and other states to refrain from all exploration and exploitation of Antarctic mineral resources while making progress towards the timely adoption of an agreed regime concerning Antarctic mineral resource activities. They will thus endeavour to ensure that, pending the timely adoption of agreed solutions pertaining to exploration and exploitation of mineral resources, no activity shall be conducted to explore or exploit such resources. They will keep these matters under continuing examination;

9. The subject "Antarctic Resources - The Question of Mineral Exploration and Exploitation" be placed on the Agenda of the Tenth Antarctic Treaty Consultative Meeting.

# IX - 2

# ANTARCTIC MARINE LIVING RESOURCES

The Representatives,

Recalling the special responsibilities conferred upon the Consultative parties in respect of the preservation and conservation of living resources in the Antarctic by virtue of Article IX paragraph 1(f) of the Antarctic Treaty;

Recalling further the history of action taken by Consultative Parties concerning conservation and protection of the Antarctic ecosystem including, in particular, Recommendations III-VIII, VIII-10, VIII-13 and IX-5;

Noting that concentrations of marine living resources are found in the Antarctic Treaty area and adjacent waters;

Aware of the need to compile more information with a view to developing a good scientific foundation for appropriate conservation measures and rational management policies for all Antarctic marine living resources;

Recognising the urgency of ensuring that these resources are protected by the establishment of sound conservation measures which will prevent overfishing and protect the integrity of the Antarctic ecosystem;

Concerned that interim guidelines for the protection and conservation of Antarctic marine living resources are desirable until such time as a definitive regime enters into force;

Convinced that provision for effective measures to conserve Antarctic marine living resources as well as for collection and analysis of the data necessary to develop such measures will require the early conclusion of a definitive conservation regime;

Recommend to their Governments that:

## I

## SCIENTIFIC RESEARCH

1. To the greatest extent feasible, they cooperate broadly and comprehensively in scientific investigations, and in the exchange of information thereon, relating to the Antarctic

marine environment and that they intensify as far as possible scientific research related to Antarctic marine living resources;

2. In planning their marine activities in the Antarctic, they have regard to the advantages that will accrue from coordination by them of their scientific investigations contributing to the BIOMASS programme;

3. They give sympathetic consideration to the provision of practical measures (such as ships, ship time, personnel and finance) in support of the implementation of the BIOMASS programme or other similar programmes;

4. They examine the possibility of integrating, in so far as is practicable, research vessel programmes with the activities of other vessels, and make available on vessels operating in the Antarctic, other than research vessels contributing directly to the BIOMASS programme, time and facilities for routine observations aimed at extending the data base for the programme.

## II

## INTERIM GUIDELINES FOR THE CONSERVATION OF ANTARCTIC MARINE LIVING RESOURCES

1. They observe the following interim guidelines pending entry into force of the definitive regime for Antarctic Marine Living Resources:

    (a) they cooperate as broadly and comprehensively as possible in the mutual exchange of statistics relating to catch of Antarctic Marine Living Resources;

    (b) they should show the greatest possible concern and care in the harvesting of Antarctic Marine Living Resources so that it does not result in the depletion of stocks of Antarctic marine species or jeopardizing the Antarctic marine ecosystem as a whole;

(c) they urge those Governments which are not parties to the Antarctic Treaty and which engage in activities involving the use of the marine living resources of Antarctica to take account of these guidelines;

2. They review these interim guidelines as and when necessary and in any event following the conclusion of the definitive regime with a view to their future elaboration in the light of the provisions of the definitive regime.

## III

## ESTABLISHMENT OF A DEFINITIVE CONSERVATION REGIME

1. A definitive regime for the Conservation of Antarctic Marine Living Resources should be concluded before the end of 1978.
2. A Special Consultative Meeting be convened in order to elaborate a draft definitive regime, and in particular:
   (a) to determine the form of the definitive regime, including the question as to whether an international instrument such as a convention is necessary;
   (b) to prepare, if necessary, draft rules of procedure for a subsequent decisive meeting for the establishment of the definitive regime;
   (c) to decide on participation in such a meeting by States other than Consultative Parties which are actively engaged in research and exploitation of Antarctic Marine Living Resources and the participation, on an observer basis, of appropriate international organisations;
   (d) to finalise the date and place of the decisive meeting;
   (e) to take any other steps in order to facilitate the work of the decisive meeting referred to above.
3. The Special Consultative Meeting shall base its work on this recommendation and take account of the discussions at the Ninth Consultative Meeting, its report and the documents presented to it, and, in the elaboration of a draft definitive regime, shall take into account *inter alia* the following elements:

(a) the regime should explicitly recognise the prime responsibilities of the Consultative Parties in relation to the protection and conservation of the environment in the Antarctic Treaty area and the importance of the measures recommended by the Consultative Parties to this end;

(b) the provisions of Article 4 of the Antarctic Treaty shall not be affected by the regime. It should ensure that the principles embodied in Article 4 are safeguarded in application to the marine areas south of 60° South latitude;

(c) the regime should provide for the effective conservation of the marine living resources of the Antarctic ecosystem as a whole;

(d) the regime should cover the area of specific competence of the Antarctic Treaty;

(e) the regime should, however, extend north of 60° South latitude where that is necessary for the effective conservation of species of the Antarctic ecosystem, without prejudice to coastal state jurisdiction in that area;

(f) the regime should not apply to species already regulated pursuant to existing international agreements but should take into account the relationship of such species to those species covered by the regime.

## IX-3

## IMPROVEMENT OF TELECOMMUNICATIONS IN THE ANTARCTIC

The Representatives,

Considering that requirements in the field of telecommunications as regards collection and dissemination of meteorological data and the need for, scientific, administrative and operational traffic have developed substantially since the second telecommunications meeting of experts of the Consultative Parties held in Buenos Aires in 1969;

Considering that the implementation of Recommendation VI.1 and VII.7, and participation in the programmes of the World Meteorological Organisation, particularly the World Weather Watch, require a thorough review and improvement of the network operating in the Antarctic;

Recommend to their Governments that they:

1. Compile comprehensive data, each for its own part, on the types of traffic, modes of transmission, timing, frequencies of their telecommunications schedules and current equipment of their telecommunications programmes in the Antarctic, as well as on projects in the process of implementation and proposed improvements, in particular by designating, where appropriate, stations capable of replacing others in the event of breakdown.

2. Forward all such data to each of the other Consultative Parties via diplomatic channels on the one hand and on the other by direct despatch to the departments concerned.

3. Arrange for a meeting of telecommunications experts to be held, on the initiative of the Government of the host country, before the Tenth Consultative Meeting, to analyse the data thus compiled, suggest desirable measures of harmonisation and put forward recommendations on improvements to be made in the operation of the telecommunications network in the Antarctic.

4. Request SCAR through their National Antarctic Committees to undertake, at the earliest opportunity, a study of the most recent applications of science and technology to the specific problems of the Antarctic in the field of propagation of radio waves, and to pass on its conclusions to the Consultative Parties prior to their Tenth Meeting or if necessary to the next Consultative Meetings.

## IX-4

## CO-OPERATION IN TRANSPORT

The Representatives,

Recalling the appropriate provisions of the Treaty as well as Recommendation VIII-7;

Acknowledging the comprehensive report on transport resources and potential requirements delivered to the Fourteenth Meeting of the Scientific Committee on Antarctic Research (SCAR);

Concurring that the most effective use of aviation assets will be in coordinated air support projects (as circumstances permit) without major additional construction or investment;

Noting that new types of aircraft, equipment, and facilities are either being developed or likely to be introduced, and the continuing need for standardization of facilities and procedures to ensure effective coordination;

Recommend to their Governments that:

1. They request SCAR, through their National Antarctic Committees, to continue the work of the Sub-committee on Cooperative Air Transport System for Antarctica (CATSA) of the Working Group on Logistics.

2. They request their offices responsible for the administration of Antarctic expeditions to adopt, to the extent practicable, such measures for improved compatibility of facilities and procedures as SCAR might be able to suggest.

## IX-5

## MAN'S IMPACT ON THE ANTARCTIC ENVIRONMENT

The Representatives,

Recommend to their Governments that they approve the following declaration on the Protection of the Antarctic Environment,

The Governments participating in the Ninth Antarctic Treaty Consultative Meeting,

Deeply aware that the Antarctic environment is unique and vulnerable to contamination and disturbance,

Determined to protect the Antarctic environment from harmful interference,

Having particular regard to the conservation principles developed by the Scientific Committee on Antarctic Research (SCAR) of the International Council of Scientific Unions,

Recalling their obligation to exert appropriate efforts, consistent with the Charter of the United Nations, to the end that no one engages in any activity in Antarctica contrary to the principles or purposes of the Antarctic Treaty,

Declare as follows:

1. The Consultative Parties recognise their prime responsibility for the protection of the Antarctic environment from all forms of harmful human interference.
2. They will ensure in planning future activities that the question of environmental effects and of the possible impact of such activities on the relevant ecosystems are duly considered.
3. They will refrain from activities having an inherent tendency to modify the Antarctic environment unless appropriate steps have been taken to foresee the probable modifications and to exercise appropriate controls with respect to harmful environmental effects.

4. They will continue to monitor the Antarctic environment and to exercise their responsibility for informing the world community of any significant changes in the Antarctic Treaty Area caused by man's activities.

IX-6

## OIL CONTAMINATION OF THE ANTARCTIC MARINE ENVIRONMENT

The Representatives,

Recommend to their Governments that:

1. They consider the possibility of preparing reports concerning the pathways by which oil may reach the Antarctic marine environment as a result of man's maritime activities in the Antarctic;
2. They include in these reports proposals relating to practicable means, if any, by which such oil contamination might be reduced;
3. They consider the possibility of instituting, in association with appropriate organisations, a programme for the determination of baseline levels of contamination of the Antarctic marine environment by oil;
4. They provide such reports as they may have prepared to, and further consider this matter at, the Meeting of Experts recommended in paragraph 3 of Recommendation IX-1, with a view to making proposals concerning these matters for consideration at the next Consultative Meeting.

# APPENDIX B

Transcript of a Public Meeting on
U.S. Participation in Negotiation of a
Regime for Conservation of
Antarctic Living Resources
December 20, 1977

Appendix B

## Department of State

Transcript of Public Meeting
on
Antarctic Marine Living Resources
December 20, 1977

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# DEPARTMENT OF STATE

The Open Meeting on Antarctic Marine Resources conducted by the Bureau of Oceans and International Environmental and Scientific Affairs, Department of State, was convened on Tuesday Afternoon, December 20, 1977, at the hour of 2:30 o'clock in Conference Room 1105, New State Building, Washington, D.C.

CHAIRMAN BREWSTER: Good afternoon and welcome to the Department of State for the meeting on Antarctic Marine Living Resources.

My name is Robert C. Brewster, I am the Acting Assistant Secretary of State for Oceans and International Environmental and Scientific Affairs.

I would like first to introduce those of us from the various government agencies who are here and then ask one member of this group to give a brief background on the subject which we are discussing.

Beginning on my right. Mr. Tucker Scully, the Department of State, Office of Oceans and Fisheries Affairs.

On his right is Mr. James Storer, the National Oceanographic and Atmospheric Administration.

On my left, Ms. Jean Bailly, the Office of the Legal Advisor, Department of State.

Mr. Ted Sellin, Polar Affairs Officer, Department of State.

And Mr. George Llano, of the National Science Foundation.

I will ask Mr. Scully if he will give us a brief introduction to the subject.

MR. SCULLY: Thank You.

I will try to be brief, and I think what I would like to do is to start with the Ninth Antarctic Treaty Consultative Meeting that was recently held in London, and then work backward to show the context in which the action of the Consultative Meeting on Antarctic marine living resources fits.

The representatives of the 13 Consultative Parties in London, in the meeting which took place at the end of September and early October, adopted a recommendation (Recommendation IX-2) on Antarctic Marine Living Resources. The recommendation has three parts:

One, dealing with scientific research with regard to Antarctic Marine Living Resources;

Another, dealing with interim guidelines for the conservation of such resources;

And the third part, which I would like to dwell on, the establishment of a definitive regime, a "definitive conservation regime" as it is called.

In the latter part of the recommendation, the representatives there present, recommended to their governments that a definitive regime for the conservation of Antarctic marine living resources be established and be concluded before the end of 1978.

The representatives further recommended that there be convened a Special Consultative Meeting to elaborate a draft definitive regime, and to answer a number of additional questions including: the determination of the form of that regime; to prepare, if necessary, rules of procedure for a subsequent decisive meeting to conclude a definitive regime; to decide on participation in that second decisive meeting; and to determine the data and place of that decisive meeting.

The representatives of the consultative parties also agreed on a number of principles which should be forwarded to the Special Consultative Meeting for its consideration in terms of incorporation into the work of the Special Consultative Meeting -- that is, elaboration of the draft definitive regime.

Then, at the end of the Consultative Meeting, the Delegation of Australia offered to host this Special Consultative Meeting to be held at the end of February. Therefore, the next step in the consideration of a regime to conserve Antarctic marine living resources will take place in Canberra at the end of February -- beginning on February 27 -- for a period of three weeks.

Now to try to place the action of the Ninth Consultative Meeting roughly in context, the representatives at the Consultative Meeting were operating within the consultative system which was set up under the Antarctic Treaty in which the representatives of those states enjoying consultative status meet periodically to discuss measures, propose measures, in furtherance of the principles and purposes of the Treaty -- and, among other things, to consider measures or agreed recommendations to their governments on the subject, among others, of the preservation and conservation of living resources in Antarctica.

There have been nine such consultative meetings since the Antarctic Treaty entered into force in 1961.

Among other actions that the consultative parties have recommended to their governments have been the Agreed Measures for the Conservation of Antarctic Fauna and Flora which have been observed by the treaty parties as interim guidelines pending their entry into force. (We now have legislation pending to bring them fully into force for the United States.)

The Consultative Parties also, back in the late '60s, developed interim guidelines for the voluntary regulation of Antarctic pelagic sealing, which eventually led to the Convention for the Conservation of Antarctic Seals -- which was concluded as a separate international agreement in London in 1972.

Much of the work, or much of the ground work, for the actual consultative meeting, recommendations on marine living resources, has been laid by the nongovernmental organization which has served, informally at least, as the scientific arm of the consultative mechanism -- that is the Scientific Committee on Antarctic Research -- "SCAR" as it is known -- which is affilitated with the International Council of Scientific Unions -- a nongovernmental umbrella organization.

SCAR was behind much of the work which led to the Agreed Measures and to the Convention for the Conservation of Antarctic Seals.

And beginning in the late '60s, SCAR's Working Group on Biology, which had addressed many of these issues, began to turn its attention to the question of Antarctic marine living resources, with specific emphasis upon questions of the resources in the Southern Ocean.

The SCAR working group on Biology, in the early 1970's created a subcommittee on the marine living resources of the Southern Ocean which was later upgraded to the Working Group on the Living Resources of the Southern Ocean.

The formation of this Working Group responded to a number of factors including the increasing interest displayed by a number of nations in the potentially harvestable resources of the Southern Ocean -such as Japan and the Soviet Union (and later Poland and West Germany) and specifically focusing upon krill, and general interest in various international bodies with increasing world needs for protein. The SCAR Working Group began to recommend or to develop recommendations for the coordination of international cooperation in the study of the living resources of the Southern Ocean, with a view to providing an adequate data base and development and implementation of conservation measures.

The Working Group recognized that the Southern Ocean, with its rather short food chain and unique ecosystem, was an area in which the conservation measures might well be needed sooner rather than later.

This issue of the marine living resources of the Southern Ocean was discussed at the Seventh Consultative Meeting, and again at the Eighth Consultative Meeting in 1975, at which time a specific recommendation was developed -- among other things, calling for expanded efforts by the consultative parties to conduct research into these resources and to further international collaboration and cooperation in such matters. The recommendation specifically welcomed the possible convening, under the auspices of SCAR, of a conference on marine living resources, which was held later in 1976 at Woods Hole, Massachusetts, data from which is providing important contributions to our scientific knowledge of Antarctic marine living resources.

The Eighth Consultative Meeting in 1975 recommended that the question be kept on the agenda and be discussed at the Ninth Consultative Meeting. It was, at the Ninth Consultative Meeting and in several preparatory meetings leading up thereto. At those meetings (both the preparatory meetings and the Consultative itself) the representatives of the 13 Consultative Parties all shared a view that the development of some arrangement or measures to provide for the conservation, or steps leading to the conservation, of Antarctic marine living resources was a matter of some urgency.

And this led to the recommendation with which I began -- Recommendation IX-2 on Antarctic Marine Living Resources.

At that Ninth Meeting the United States, which supported Recommendation IX-2, set forth preliminary views on a regime to conserve Antarctic living resources in the general statement made by Ambassador Brewster. We made five points with regard to the development of a conservation arrangement which, as we stated, is required:

First, that such a conservation arrangement be directed to fishery resources, and not applied to species already regulated pursuant to existing international agreements -- i.e. whales pursuant to the IWC, or seals pursuant to the Convention for the Conservation of the Antarctic Seals -- when it comes into force -- provided that such arrangements take into account the relationship of such target species to other species and to the Antarctic ecosystem as a whole.

Secondly, we made the point that such a conservation arrangement should provide for effective conservation of the species that it covers, throughout their entire range.

Third, that such an arrangement should provide for and encourage participation by all interested states.

Fourthly, that it should provide for an institutional mechanism, a separate institutional mechanism which would both develop and implement conservation measures themselves and provide for the necessary collection and analysis of data which would provide the basis for effective conservation measures.

Finally, we stated the view that such a conservation arrangement should provide for effective enforcement to insure compliance with conservation measures.

Now, following the Ninth Consultative Meeting, we stand on the verge of opening negotiations on the details of a conservation regime -- such a negotiation will begin at the end of February in Canberra. We are beginning the process of developing our specific positions -- our policies on such a regime -- and it is in that context that this meeting is taking place. It is in that context that we are moving to develop a draft Environmental Impact Statement and taking a number of actions to insure that we get our own house in order in the federal government and that we have the views of the interested public in trying, in this case, to develop policy in as rational and as open a fashion as we can.

Having said that, I turn it back to you, Sir.

CHAIRMAN BREWSTER: Thank you, Tucker. I open the floor to comments.

MS. PAT SCHARLIN: Tucker, could we get into any discussion at all on what the United States views as the meaning of "conservation" in terms of its conservation regime? This is always a question, I think, that puzzles us most.

MR. SCULLY: Well, let me start by saying that we are delighted to have your views on what the concept of conservation means, as well.

There is, as you know having been at the London meeting, potential for a number of divergences in view as to what the concept of conservation means.

I think that at the Consultative Meeting itself there was some concern expressed by representatives of countries who have an interest or potential interest in the harvesting of the resources that the term "conservation" also includes an element of what is described as "rational utilization."

In other words, there was some fear on the part of states with exploitation interests, that the term "conservation" by itself, could be interpreted as meaning no harvesting whatsoever of any of the potential resources of the Southern Ocean.

I am not sure how many of you have received copies of the report of the Ninth Consultative Meeting.

There was an agreement among the participants, which was not included in the recommendation, Recommendation IX-2 itself -- but in the report -- that the term "conservation" did imply rational utilization. In other words, the term conservation is not inconsistent with the concept of harvesting -- but that it does mean in some fashion the application of standards and criteria to any harvesting that might take place, so as to ensure that such harvesting would not result in overexploitation of a single species or of harm to the dependent species, or to the Antarctic ecosystem as a whole.

But I think, again, the concept of what is meant exactly by "conservation" is certainly a subject on which we would like to have as much advice as possible.

MR. GOTTSCHALK: Mr. Ambassador.

CHAIRMAN BREWSTER: Yes, sir.

MR. GOTTSCHALK: My name is John Gottschalk. I am representing the International Association of the Fish and Wildlife Agencies; and at this point I think it might be appropriate for me to insert in the record our views on this subject, particularly since I am going to have to leave the meeting a little earlier -- so if I may --

CHAIRMAN BREWSTER: Please, Mr. Gottschalk.

MR. GOTTSCHALK: I will proceed. Now the International Association of Fish and Wildlife Agencies is a voluntary organization of state and federal agencies in the United States, Canada and Mexico. Our charter incorporates the entire Western Hemisphere but because of preoccupation with domestic affairs in the United States we haven't been able to attract any members in South America.

Nevertheless, our members are concerned and interested in this whole problem.

I would like to say, to start with, that we find ourselves in basic agreement with the position of the United States and the countries in the last meeting -- as we understand them. We feel that it is essential that a conservation program or regime be established to guarantee the future productivity of the living resources of the area encompassed by the Antarctic Treaty.

Further, we are pleased that the emphasis has been placed on the acquisition of knowledge through scientific research. These concepts are essential for any useful and effective conservation program for a vast and vital area of the earth's surface.

It is, of course, absolutely essential that these concepts be embodied in working programs before there is any wholesale effort launched to begin the commercial exploitation of the resources of the area.

Perhaps it is unnecessary to point out in this group that where there is a substantial commercial stake in resource development there are usually powerful forces at work to frustrate these basic principles of conservation. Hopefully, the United States can be a leader in promoting the rational utilization of the living resources found in the Antarctic seas, rather than a passive observer of their exploitation.

At the very minimum, our posture should be to insist upon a conservative approach towards the protection of these resources.

If there is to be utilization, then let us do what we can to assure the long term viability of the resource base.

Tied in with and perhaps basic to this position is that of advocating the principle of optimum, rather than maximum sustainable yield.

Granted, there are real and difficult problems in defining the output yield in general, but nevertheless it is the best means of insuring prior recognition of the possibility of indirect adverse effects of exploitation.

Then certainly, any utilization of krill, for example, must be done with one eye on the impact of such activity on the sea bird population. Not only has that population an intrinsic value of its own, it may well serve as a vital nutrient transfer mechanism that recycles krill into the nutrients that keep the whole system producing.

The need to have these ecological considerations in the forefront of the decisionmaking process is underscored by the fact that the Antarctic Ocean ... is characterized by few species but vast numbers of individuals.

In these situations, population dynamics take on properties different than those expected in more temperate climes where there may be a greater diversity of species. The level at which exploitation can be expected to be sustained is apt to be underestimated in the presence of great numbers of individuals, as in the case of the euphausia.

In America in particular, with its history of wanton destruction of the bison, the passenger pigeon -- to name only two species -- we should be all too sensitive to the need to approach utilization with consummate care.

At present, the nations signatory to the Antarctic Treaty are essentially the only ones involved in the decisionmaking process as it relates to the living marine resources. History has shown time and again that it is imperative to gain the support of all those whose support will ultimately be needed in a program, by enlisting them in the planning process at the earliest practicable date.

Therefore, it seems apparent that steps should immediately be taken to bring into the purview of the protocol for the conservation of the Antarctic living marine resources, those nations which have now, or shortly will have, or may have, an interest in these resources

Furthermore, in the light of the potential interest of many countries who have as yet ill-defined ambitions for participating in one way or another in Antarctic affairs -- it would seem prudent to have the Food and Agricultural Organizations of the United Nations, and perhaps UNESCO as well, as full fledged partners in the endeavor. Not only would this bring these groups into a cooperative role but would also make possible direct contributions to research and management by the U.N. organizations.

A few years ago an economist looking academically at the the whale resource, concluded that for maximum economic return it would perhaps be best to exterminate the world whale population and exploit directly the krill and other forms at lower trophic levels in the energy sequence.

It is being neither unrealistic nor apprehensive to say that as the world's food sources dwindle in relation to demand, we will hear more of this line of reasoning. It of course denies the inherent right of forms of life other than homo sapiens to exist in a natural state on this planet.

Without belaboring this point, we suggest that the world is still some generations away from reaching such a condition. In the meantime, therefore, it is essential to do what we can in man's own interest, to protect and enhance the productivity of the natural biotic systems of the earth. We have surely learned that it is possible to use without destroying, to manage on a sustained yield concept. We trust that it will be the policy of the United States to do its utmost to advocate and establish these concepts as they relate to the living marine resources in the Antarctic.

Thank you for this opportunity to give this statement.

CHAIRMAN BREWSTER: Thank you. Yes?

MR. JAMES BARNES: Thank you, Ambassador. I am Jim Barnes, and I would like to turn for a few minutes to the point before, about conservation and what that might mean.

In the report, and the pages aren't really numbered here -- but it's point number ten -- it's explicitly stated: The Working Group agreed to include in its report the understanding of the Group, that the word "conservation" as used in the draft recommendation, includes rational use in the sense that harvesting would not be prohibited. But the regime would exclude catch allocation and other economic regulations of harvesting.

Now I think one of the principle concerns that most of the organizations at the Center, that the Center works with in many environmental areas, and specifically Antarctica, is this concept of economic regulation and what is not included, or what may be excluded from this regime we are trying to set up.

Because it seems to us that you cannot have a sound living resources regime without it being based on management and some conservation principles -- and we don't really see how you can have sound conservation and management principles embodied in a regime if you are going to exclude all catch-all cases -- and what I am afraid might be included in this phrase "other economic regulation of harvesting."

And specifically we would like to know, I guess, whether in the view of the State Department the term "economic regulation" includes things like catch limits -- gear restrictions -- effort restrictions -- closed seasons --closed areas and things like that. Because if that phrase does include those things, and we are excluding them from the regime, it is difficult (in the opinion of many environmental groups anyway) to have an effective management regime.

MR. SCULLY: Could I have just one point on that? I think that it is not our understanding that those terms would exclude any of the conservation measures that would or could be applied to regulate harvesting.

MR. JAMES BARNES: What about catch allocations which are specifically delineated?

MR. SCULLY: The reason for the inclusion of catch allocations was that it was the understanding of those participating that they would not devise, at least at this stage of the game -- national quotas.

There would be total allowable catches.

There could be quotas but not in the regime itself.

There would not be a specific, as I understand it, division between country x, country y and country z --

MR. JAMES BARNES: But you are anticipating that the regime initially even will try to establish a total quota for krill, for example?

MR. SCULLY: Yes, that would be one form of conservation measure we would see as being envisaged. Yes.

MR.JAMES BARNES: What was intended with this phrase "other than economic regulation of harvesting", then?

We don't understand -- I think I speak for many groups in saying this -- that we don't really understand what other economic regulation of harvesting encompasses -- and what the intent of the people who drafted this, was -- what it's intended to cover, by employing that phrase.

MR.SCULLY: Well, I will speak for what my understanding of what the phrase means, which is that it was not intended at this stage to engage in dividing between specific nations the allowable catches which could be set pursuant to the regime -- which the regime would envisage.

DR. AUBURN: Sorry, I'm Francis Auburn, from the University of Auckland.

To keep on with this I think this is a vital point.

The words used are: "catch allocation" and "economic regulation" or "and other economic regulation."

Now "catch allocation" would clearly be excluded.

The point we have to return to, I think, is a vital point: -- what does "economic regulation" mean? Obviously, it doesn't include catch allocation -- what does it include? Because there is the considerable feeling that if "economic regulations" is interpreted widely, including these measures we have looked at here, then the practical consideration of the essential parts of a regime may not be worth much.

Well, to get back to: What does economic regulation mean? What does it mean in this fine report?

MR. SCULLY: I think your point may be well taken and I think that, if in fact the interpretation can be that it would preclude certain kinds of conservation regulations, we would oppose it. We would certainly oppose that interpretation of it.

It is our view, at least our preliminary view included in the general points that we made at the meeting itself, that the "conservation arrangement", as it was called at that time, to be established would in fact be specifically called upon, or would be specifically empowered, to develop and implement all necessary conservation regulations.

And if the interpretation -- if an interpretation of that point in the report is contrary to that, then I think we would certainly have to be ourselves aware of it: (a) in developing our position on this issue; (b) and then once the position is developed, in trying to negotiate it.

MR. JAMES BARNES: Could we ask whether the United States in the context of these recent negotiations made a commitment of any sort to other nations in return for getting unanimous agreement on the recommendations set up for the regime? If they made some kind of a commitment not to push for some of these economic -- or what I would call "economic regulations" but maybe that's a term we should not be using because we don't understand --

But you know -- things like allocations, gear and effort restrictions?

CHAIRMAN BREWSTER: No, it did not. Let me make two comments about this phraseology, which may be helpful:

One, it appears in the report of the Working Group. It does not appear in the recommendation itself.

Second, it had its origin in a concern expressed by several states which are active in exploration of krill and perhaps could be considered as moving most rapidly toward commercialization.

The concern was that the recommendation, as it stood, did not make clear that conservation should not be interpreted to prohibit all catch of krill. That definition was not incorporated in the recommendation. It found its way into the report of the Working Group because the United States, as did other countries, agreed that the term "conservation" did not exclude exploitation of krill.

MR. JAMES BARNES: Well, I think one of the things -- and this is really good to know because there has been an awful lot of concern among organizations that we deal with -- having looked at the recommendations and so forth and not seeing anything --

Seeing a lot of very nice thoughts about conservation, etc. -- but not anything about how you actually work it out.

And that, coupled with this kind of language expressed -- has led to a lot of concern about exactly what kind of regime is going to be set up. And I might say that some of the information that we come across, comes from overseas where people have access to other sources of information -- from other governments -- and none of that information has been very positive in this regard.

And it is, I think, widely thought in the environmental community that this regime is going to be a weak regime, etc, and won't have any teeth. And that really, I think, furnishes the major focus of our concern as we approach this critical drafting stage in February in Canberra.

CHAIRMAN BREWSTER: We can't predict what kind of a regime it will be.

I would reiterate that the five principles that we went to the Ninth Consultative Meeting with, and which were largely encompassed in this recommendation, and one of those is certainly an enforcement system, remain the governing principles of the administration.

As Mr. Scully indicated, we have not finalized our ideas on the nature of this regime. Indeed, we have no draft regime and no draft convention to suggest. We will be elaborating those on the basis of our meeting here today, some consultations I expect to have together with Mr. Scully later in January, and further studies in the EIS. But our efforts are certainly going to be devoted to achieving a legitimate conservation regime, one with teeth in it.

MR. JAMES BARNES: Would it be the State Department's current intention to propose to the next special session, for example, that all the traditional elements of a sound conservation and management regime be included -- such as the one to catch limited -- for catch limits -- different kinds of gear -- and effort restriction -- closed areas -- all the things that would logically be incorporated into a sound conservation --

CHAIRMAN BREWSTER: I really haven't gotten that far.

MR. JAMES BARNES: When will the draft EIS be available?

CHAIRMAN BREWSTER: February 1st, and I hope to distribute it within a week, and have a public meeting subsequent thereto in order to receive initial comments on it before decisions are taken on our negotiating position.

Then there will be the usual 45-day period which I assume will transpire before what we anticipate to be the conference to draft the final definitive regime, or convention, takes place.

We use the word "definitive regime" because the term "convention" was one which at least one country could not accept in a written document.

MR. HARGROVE: I am Larry Hargrove, of the American Society of International Law; I had a couple of questions growing out of this discussion:

One is this: It would seem to me from the very fact that the recommendation includes the Section 2 interim guidelines, which are directed toward continuing exploitation activities.

And also from the explanation that has been given as to the meaning of a conservation regime -- i.e. it is interpreted as envisaging the possibility of exploitation as opposed to no exploitation.

It would seem to me that from these two factors one could resonably conclude that the political judgement of the participants in the meeting was that a moratorium on exploitation of the presently commercially interesting species was not achievable -- leaving aside the question of whether it might be desirable.

Is that a correct appraisal? Does the United States have any independent judgement on the desirability of the moratorium, leaving aside the question of its political achievability?

And if so, what is your expectation as to the position you might take in the coming negotations?

That is one question.

CHAIRMAN BREWSTER: Yes. With respect to your first question, the idea of a moratorium was not, to my recollection, explicitly discussed.

Was it in your Working Group?

MR,SCULLY: Not as such.

The question of a moratorium, at least a temporary moratorium on harvesting, is an option that we will be considering and will be considered with the EIS. And therefore, I think that it's a question on which our minds are still open.

We would have to, in making and developing our policy on our negotiating positions as we go along -- try to make some reasonable judgements as to what the negotiating situation is -- make some political judgements as to what we can can do.

And, of course, one will have to be looking at two objectives, let's say, between which there may be some tension. One of these is to establish the conservation regime which is as effective as possible in the conceptual sense. This would argue, perhaps, for a moratorium until all of the necessary machinery etcetera is in place and working.

On the other hand, if one wants a conservation regime to be effective, it has to include all those who engage in activities relating to the resources involved. There may well be states which are interested in possible commercial harvesting in the near future that would resist a moratorium very strongly.

But this is the kind of process -- making those kinds of judgements will be the kind of process that we are beginning now in looking toward the negotiation, or the beginning of negotiations.

MR. HARGROVE: I would gather then, from what you say, that you haven't ruled out the possibility of putting on the table, or discussing if somebody else puts on the table, an interim moratorium of some sort -- notwithstanding the fact that the Germans or the Soviets or others might find that a distasteful component of a conservation and management regime.

CHAIRMAN BREWSTER: No, we would not.

MR. HARGROVE: Let me ask another question: The position with which you went into the recently concluded meeting, particularly in respect of the fifth point which speaks of effective enforcement arrangements -- as well as your introduction a few minutes ago, Mr. Scully, would seem to me to suggest that you have in mind that a treaty is the end product of this negotiating process. That certainly would be consistent with the analogy of the sealing convention, for example.

The recommendation, however, in its Section III envisages that the Special Consultative Meeting will, among other things, determine the form of the definitive regime, including the question of whether it ought to be a convention.

Is it the U.S. position that a treaty ought to be the end product?

And if not, how would the United States, or states which may favor some other form, envisage putting an effective management regime, particularly one with some enforcement measures, into effect?

CHAIRMAN BREWSTER: It is the United States' position that a treaty should be the end outcome of this process. As a matter of fact, our preference was that the Antarctic Treaty powers provide, as the next step, for the calling of a conference to write such a treaty.

The result was instead what you see -- which is a special meeting of the Consultative Parties to do a draft, and then to decide on the further step.

There was almost complete unanimity on the necessity for a conference which would result in a convention or treaty. Those were not the precise words used. The recommendation speaks of a "definitive regime" and uses circumlocutions, but the understanding of all of us was that that would be the outcome and it is our hope and expectation that when we meet in Canberra there will be unanimity on that, in proceeding directly to that.

MR. HARGROVE: Could I add one point to that?

CHAIRMAN BREWSTER: Surely.

MR. HARGROVE: I think that it is also a logical consequence of our position that a conservation regime should apply to the full range of species covered -- that a treaty would be required as the instrument in which to frame that conservation regime -- because, that means going more than 60 degrees South Latitude.

CHAIRMAN BREWSTER: That is to say, if the alternative to a treaty would be an agreed measure --

MR. SCULLY: From a practical point of view, I don't know that any other alternatives have been put forward, other than something like agreed measures done specifically pursuant to the Antarctic Treaty and specifically limited to the Antarctic Treaty area.

CHAIRMAN BREWSTER: There was general agreement that in fact a regime would have to go north of 60 degrees South. We had anticipated that this might in fact be a stumbling block, but after initial discussion it did not turn out to be. There was, I think, unanimity on this point, was there not?

MR. SCULLY: On that part.

CHAIRMAN BREWSTER: And by definition it would have to be handled by the treaty.

MR. GOTTSCHALK: One other question, if I may.

CHAIRMAN BREWSTER: Yes, sir.

MR. GOTTSCHALK: Along these lines we are obviously concerned about the nature and amount of regulatory mechanisms that might be needed and put into force, and it occurs to us that this is going to require some kind of a management authority established under any treaty that might come up.

Would this be covered in the Environmental Impact Statement in detail, so that we could analyze the character of the machinery that would be established with respect to the capability for management -- including enforcement? Would this all be covered by EIS, or would it just be tacitly assumed that there would be a system development?

MR. SCULLY: If I could make one point on that. Looking at the question of drafting an EIS, one has to reach some happy medium between trying to anticipate in detail all of --

MR. GOTTSCHALK: In other words there is an infinite array of --

MR. SCULLY: Exactly, yes.

A specific or proposed management system with all of the necessary details filled in, I think that is one extreme--

And the other extreme is just to assume a mechanism.

What we would hope to do in the EIS is to try to meet both concerns somewhere in the middle. In other words, try to have some description of the kind of mechanism that would be necessary in terms of the functions it would perform -- and in a kind of general outline, without trying to get too specific concerning the details.

MR. GOTTSCHALK: So in effect, you would set forth a series of management principles without being specific as to how they might be employed?

MR. SCULLY: I hope so.

MR. GOTTSCHALK: For example, you need to have some population estimates , and estimates of the impact of a particular rate of exploitation -- and a lot of other things of that nature.

Hopefully, if those could be set forth well enough so that we get some handle on how effective they might be.

MR. SCULLY: Well on that point, if I might continue a bit -- It's hard to say how far one can go in discussing population dynamics and stock assessments or whatever because we are still dealing in an area where we don't have the kind of data base and establishing the means for not only assessing and assimilating basic scientific data, which may already be available -- but also for providing a means for incorporating and assessing catch data or other kinds of statistics and providing an effective mechanism which would provide a digestible data base upon which to base the necessary conservation measures.

I am not sure how far one can go in that sort of thing, in advance --

MR. GOTTSCHALK: You certainly can't fill in the specific figures, but there might be a general outline of the approach.

MR. STORER: Well the principles you would use and what you would need in order to determine the management measures -so you wouldn't include in the EIS the actual data --

MR. GOTTSCHALK: No. But you would expect that the kinds of influences -- the approaches you would use to establishing measures, would be excelled.

But again, there is a wide array.

MR. SULLIVAN: Mr. Ambassador, my name is Carl Sullivan and I represent the American Fisheries Society and I would like to read a statement into the record if I might.

I do have it in letter form and will give the reporter a copy.

The American Fisheries Society (AFS) supports the negotiation among the interested nations of the world of a regime for the conservation, rational utilization and management of fisheries in Antarctic waters. The Society's interest stems from concern for the fisheries of Antarctica for the Society, chartered in 1870, is the world's oldest and largest scientific/professional organization dedicated to the advancement of fisheries science and the conservation of renewable aquatic resources.

In the negotiation of the Antarctic fisheries regime we urge that careful consideration be given to the inclusion of the following provisions:

1. Research. The regime should provide for an accelerated, fully coordinated fisheries research effort with particular emphasis given to development of an inventory of all renewable resources plus an estimate of recruitment potential. No utilization/management regime will have much chance of success unless it is based upon a comprehensive understanding of the resource. Every signatory nation should make a commitment to this end.

2. Interim Exploitation. During the negotiation of a management regime it seems likely, and not unreasonable, that some exploitation of Antarctic resources will continue. We urge, however, that caution will be the guiding principle in any such interim exploitation. The often tragic consequence of overharvest should be familiar enough to every country so that such a scenario will not be repeated in Antarctic -- the last of the world's virgin areas. A pledge of harvest moderation from all nations would not only protect the resource but would improve the climate for negotiations.

3. Optimum Sustainable Yield. In the absence of a better plan, the American Fisheries Society supports management for OSY with particular attention given to a broad ecosystem approach in which the stocks of all organisms are viewed not only for their potential yield to man but in terms of their relationship to all other organisms in the Antarctic ecosystem.

4. Pollution Abatement. Even though the Antarctic may be already somewhat contaminated by modern civilization's debris, no effort should be spared in preventing further degradation. From the outset of negotiations every nation should be expected to affirm a strong commitment to prevent all forms of pollution plus a strategy for surveillance and enforcement.

American Fisheries Society believes that it is possible for man to make highly beneficial use of of the vast renewable resources of the Antarctic. In utilizing these resources, however, we see many threats to a healthy environment. Experience teaches us that even single nation management regimes in comfortable climates are far from perfect. Implementation of a successful management multinational management regime in the world's harshest climate will perhaps be the toughest challenge ever faced in fisheries diplomacy.

CHAIRMAN BREWSTER: Thank you, Mr. Sullivan.

MR. SULLIVAN: Thank you for the opportunity to be heard; and I will pass these copies along to you.

MR. CHAPLIN BARNES: Mr. Ambassador, I am Chaplin Barnes, of the National Audubon Society. I know that on numerous occasions you have said that you favor the creation of a public advisory committee. Since you favor the creation of a public advisory committee, I wonder where the thinking of the Department now is on that issue -- and whether that's the form that you are going to go for -- or what we might expect.

CHAIRMAN BREWSTER: I can very easily answer what the thinking of the Department is. I have more difficulty in replying what the action of the Department is. (Laughter.)

I still wish, and so does the Department wish, to establish an advisory committee. There is, as I think you are aware, a general attempt on the part of the Administration to cut down on the number of advisory committees, and it has to be acknowledged that there are a large number of them whose purposes and existence are perhaps questionable. So that has been the practical impediment to our doing it.

What I am currently hoping to do is to utilize one of the presently authorized and established committees of the Department and to create in that an Antarctic section that obviates the necessity for an approval at various levels both in the Department and in other government organizations. That is what I am attempting to do.

I am unable to say (a) whether I will be successful; or (b), when.

MR. JAMES BARNES: To follow that up a little bit, one of the other things that I think has concerned a lot of us about our role in forums like this, is our access to data and I would just mention one thing specifically that came up in the last couple of weeks:

We tried to get access so that we could comment on them -- to the drafts by other nations of the proposed living resources regimes, and we were told that we couldn't have those, at least at this time.

It makes it a little bit difficult for us to comment intelligently on, you know, the real world --. which is the world of the Antarctic consultative parties negotiating -- if we don't have access to that kind of information and data -- and it is often the case in our experience that advisory committees can circumvent that particular problem because of the restrictions on the information.

CHAIRMAN BREWSTER: Precisely, and that is one of the reasons that I had planned, beginning now a year ago -- and that was a year ago in November -- to establish an advisory committee precisely for that reason.

But absent the advisory committee, we are faced with the fact that the practice of the Antarctic Treaty is to classify, or to treat as classified, all of its documents and we are required to so hold them.

Those documents submitted by the United States have a different status, and we have made them available.

Within the Antarctic Treaty, specifically the Ninth Consultative Meeting, the United States fielded a proposal to change this system, and it was met with great approval in private but no support in the plenary meetings whatsoever. In fact, the references to the United States proposal for the requirement for greater information being made available to the public and the fact that the declassification of documents had been discussed was at one juncture deleted from the final report. It was put back in, and it will be on the agenda of the Tenth Consultative Meeting.

I have to add that the apprehension some of our partners in the Antarctic forum feel is justified. There are some delegations which are able to submit working papers and to discuss ideas and proposals in the Antarctic Treaty forum which they are unable to discuss in their own countries and, I suspect, they may be unable to discuss with certain officials in their foreign ministries. And they are apprehensive that a release of documents, or a system which would require the Consultative Parties to classify those documents they wish to classify

-- would create problems for them.

MR. JAMES BARNES: Well, would it be useful to conceptualize this as being composed of several parts and, putting aside all the other range of documents that we may be talking about and letting the conventional rules apply to those at least for the time being -- and take out as one category, all the documents that relate to the living resource regime (which as we all see is going to be drafted outside, at least partly outside the context of the Antarctic Treaty anyway) and you know without access to those documents, it makes it rather impossible for interested members of the public, anywhere in the world, to have the kind of input that I think you and our government at least, feel they should have.

I think that those documents in fact, are quite different than some of the ones you may be referring to and I can't really see why there is such a great problem in releasing those -- unless the institution of the consultative parties as a group, feel that by giving those documents they will breach their general position irrevocably in some way.

CHAIRMAN BREWSTER: That is one concern, and the other is that they may refer to other documents or other discussions which they are unwilling to declassify or to make available.

I have to honestly state that I don't think that at this juncture there is anything I can do about that.

MS. SCHARLIN: Mr. Ambassador, I wonder if we can talk a little bit about the whole question of the territorial claims raised in my letter, and which you did answer.

But I wondered if you might elaborate a little more on how Article IV could be, perhaps utilized to deal with this issue -- especially if the conservation regime does extend to the full range of the species.

CHAIRMAN BREWSTER: To be used with respect to marine living resources?

MS. SCHARLIN: Yes.

MS. BAILLY: I think, Pat, that it remains to be seen what develops in the negotiations and in consultations before the meeting. But a possibility is sort of the way it was treated in this agreed recommendation. There is a principle, in Section III Number 3, Subparagraph d which is not really terribly different that the principles that are embodied as well in the Antarctic Sealing Convention, which would be a precedent.

And I think Article II in that convention has -- it's a disclaimer in fact -- it goes about setting up the regime and the mechanism -- and then there is a disclaimer on it which basically says that the provisions of Article IV are not prejudiced by this regime.

That's a possibility, and then you would just do the rational kind of conservation regime that you, hopefully, could negotiate. That's a possibility.

But it remains to be seen just how it all comes out -- but that's the way it came up in the Sealing Convention.

MS. SCHARLIN: Are there other alternatives that you might have to be worked out? In other words, in terms of the reaction of a certain -- of the claimant states -- would there be other alternatives in dealing with this?

MS. BAILLY: Well I think that is a point.

MS. SCHARLIN: That seems to be one -- I get the feeling, you know -- "what else?"

MS. BAILLY: I think at this point we are obviously not going to recognize some kind of 200 mile zone given the United States position.

CHAIRMAN BREWSTER: That's one alternative which several countries have asked us to embrace. We have declined to move to their position -- and will continue to decline.

MS. BAILLY: Well I think, given this agreed recommendation, it was unanimously agreed upon, that kind of approach could be anticipated.

DR. AUBURN: Has somebody got an idea of what the actual annual catches were of krill -- of either the Soviet Union or Japan -- or even over the last five years? Have you any figures on that?

COMMENT: I think they are relatively slight.

The Russian one varies from something like the recent years of 2,000; perhaps up to 10,000.

The Japanese is perhaps one or two thousand.

MR. JAMES BARNES: Is that tons a year?

(Confirmed, yes.)

MR. SCULLY: I think I have seen the figure of a maximum in any of the years -- and these are fairly rough estimates based on FAO data -- of a maximum in any given year in the vicinity of 20,000 total.

CHAIRMAN BREWSTER: I think we have to add the caveat that we are not certain that these are precise. These are estimates, aren't they?

MR. STORER: Right.

MR. JAMES BARNES: Could I return for just a minute to the claims point?

Is it conceivable, or is this a problem that we have to be aware of -- that if we established a regime that had what I would call "effective, sound conservation management principles and enforcement mechanisms" that some of the nations who are most aggressive in pursuing their territorial claims would at that point, insist on a recompense of some sort, or recognition of their claims to be effected by this regulation? I mean, is there any kind of a linkage there at all?

Or is it your understanding and feeling that these nations are going to agree to agree to adhere to a living resources regime without regard to their territorial claims -- and we can just sort of leave them separate and aside?

CHAIRMAN BREWSTER: Subject to what you two gentlemen have to say, it is not my feeling that we know the answer to that yet.

The first idea that you mentioned has at least been surfaced informally in the discussions. But for myself, I don't think I know which way I think that one is going.

Do you or Jim have a feeling?

MR. SCULLY: I think one can only look at and assess some of the forces that are operating upon the nations involved; and though it's probably difficult and a little bit presumptuous to try to put oneself in the place of, say, a nation which is strongly attached to its territorial claims.

One could at least postulate that there is in such a country a political desire to insure that its position on territorial claims might prevail.

There also may be countervailing forces which involve the honest recognition that there is a conservation problem that can only be solved through some form of an effective international agreement.

So I think that at least there is some ground for arguing that there is hope for a consensus which will help to achieve an acceptable objective for all concerned.

MR. JAMES BARNES: What would the U.S. do, or what do we think we might do if it were presented in the context of this next special session that "country x" refused to sign onto a limited resources regime unless its claim were -- you know -- given some recognition by -- even a token payment -- for example, something that would in effect go beyond the provisions of Article IV and actually enhance their claim.

Do we have a position on that? Are we going to have a firm position on that?

MS. BAILLY: That's extremely unlikely to happen, given this unanimously agreed document that specifically raises that compromise and says that the compromise is not to be upset. I think that would be extremely unlikely and I think think that we would go back to this document.

I think the understanding was quite clear at the meeting as well; so that it would be very unlikely, I think.

CHAIRMAN BREWSTER: I only said, that doesn't mean it won't be raised.

MR. JAMES BARNES: As to a moratorium again, is this an idea that the United States might consider presenting at the next session?

Because I think there are a number of groups -- in fact, we have considered submitting a statement today but we don't have it in a fashion that I think would be appropriate to submit -- but I think there would be general concensus among most of the environmental groups that we have talked to, that an interim moratorium along the lines of what the American Fisheries gentleman suggested, makes an awful lot of sense in view of the paucity of data that we have about the area etc.

And we recognize that there are political difficulties with doing that, especially since we are harvesting ongoing -- and we are prepared to suggest a sort of modified moratorium which might go along the lines of a commitment by nations not to fish for more than they are now fishing for -- until such time as we have adequate base line data and other information that you really need to establish a rational conservation management regime.

And looking towards that concept of optimum instead of maximum return of the resources.

CHAIRMAN BREWSTER: Certainly we would consider it.

I also would have to tell you that my present opinion -- and as I said earlier the position of the State Department or the U.S. Government has not been determined -- but my own present view of that is that it is in all probability something that one could not negotiate.

To the best of our knowledge, the commercial exploitation of krill is not yet a fact. We are aware of its appearance in various markets in certain forms, but I don't think that the whole process of commercialization has yet been developed.

The information we have, however, strongly suggests that commercialization could happen rather rapidly. I would assume that the countries that are working on that most assiduously (of which the United States is not one) would be precisely the countries which would have difficulty with that kind of an approach now. That attitude is in part reflected in the words of the working group which we previously discussed and which we agreed to the assurance that "conservation" did not mean no "harvesting".

So on the basis of what I know now, I would have to say I think such a proposal, desirable though it might be, is probably not negotiable. But I come back to say that we will consider it.

MR. JAMES BARNES: Well I think the point to stress here -- and I haven't heard anybody I've talked to who are here today, suggest sort of a complete moratorium.

CHAIRMAN BREWSTER: Yes --

MR. JAMES BARNES: What has been suggested is what we have characterized as an "interim moratorium" which I don't personally see as being inconsistent with the language necessarily that was drafted because that looks towards, you know, the long term.

And the point here, is that it may be impossible to establish a really rational conservation and exploitation scheme unless you have the data and if exploitation was to take place in a rapidly increasing scale over the next five or six years at exactly the time that the key data is supposed to be getting assembled -- it would be an impossible situation.

And that's where the context -- I think most people I have heard discuss an interim moratorium, have raised the idea.

Do you have the same feeling that even that formulation is really politically tenuous?

CHAIRMAN BREWSTER: I am not sure I would accept the premise that "if commercialization does start then regulation would be impossible."

MR. JAMES BARNES: Well, large scale -- if it really went in a mammoth --

CHAIRMAN BREWSTER: If the regime which is negotiated provides a mechanism for doing that, and if, let us say, it does not provide for unanimity, I would think we might well have the mechanism and also the scientific data for some sort of mechanism to produce both the data and the action.

MR. STORER: Let me make a point on that comment which is an interesting one:

One of the proposals for management put forward by a consultant for FAO, his own concept, was that you might, in the Antarctic, (once you had a convention and a mechanism), establish a fairly low total allowable catch figures.

And then have fairly small allowable incremental margins in any one period -- let's say a year -- so that you wouldn't assumedly have in any one period, a doubling of the catch, but you might allow only ten percent increase a year by any country and be able to review this annually to see what the impact is.

While that is just a proposal, it is an intriguing one.

MR. JAMES BARNES: It sounds very responsible to me.

MR. STORER: Yes, and it's one of the nice things about -- if we get this thing going in time, it would be a first time we might be able to look at this and to consider growth intelligently, with some ability to --

It's just an individual proposal made by a consultant.

MR. JAMES BARNES: No. I like the propsal. I think it is very interesting and good.

And along that line, one of the things that some of the people who have consulted with us about this, as suggested, is that there are many ways to use krill.

For example, it -- when it appears that historical stocks of the (baleen) whales are down, you know, to ten percent of their historical level -- and some people suggest that -- of course they eat a lot of krill -- and if they were returned through a sound management scheme to their historical levels (which is certainly possible) -- but it's not possible with large commercial exploitation of krill arguably -- that would be an assured, and very high quality protein resource of so many million tons.

It probably wouldn't be anything of the size that you have heard bandied about 50 million tons a year or whatever, of krill -- but it would be a certain kind of protein resource -- and that is an option that a sound regime could consider.

And those are the kinds of interplays and considerations we think are really important, you know, to deal with; and as I say, we have a unique opportunity here to deal with -- starting from the position that we haven't already decimated the stock, we can be intelligent about what we do.

Mr. HARGROVE: Larry Hargrove again, from the American Society of International Law.

It would seem to me that the model, which has perhaps implicitly been in the minds of all of the states participating in this embryonic negotiation thus far, is that of a fairly typical high seas fishery conservation management regime

-- a negotiating model and a model that would guide the end product (although there are some special twists that would apply with respect to resources in the Southern Ocean.)

There are, however, some different models of recent experience as regards international negotiations for the management of ocean resources; and in that connection I wonder -- models which might recommend themselves to certain states either participating or not participating in the discussion of these negotiations --

So for that reason I wonder if you feel under any pressure from any source to broaden the participation in these negotiations beyond the class of states that are mentioned in the recommendation, which is a fairly narrow though not unreasonable class -- namely --I gather the consultative parties that are actively engaged in research and exploitation.

MR. SCULLY: Let me try to answer that.

Obviously that question raises a number of very broad issues, but let me try to put forward a few ideas that occured to me in response thereto.

First of all, I think from the juridical point of view, the concept of the high seas basis of regulation has been a very appealing one to the United States given its position on territorial claims.

But leaving that aside, I think that the question you essentially raise is a common heritage question, or the question of the distribution of the potential benefits from the exploitation and potential exploitation of new sources of protein in the Southern Ocean.

It has been our view, or at least in preliminary fashion, that what we are essentially now addressing is a conservation regime and the requirements for conservation are what lie behind the standard for participation in the negotiations.

In other words, these requirements are to make sure that all those countries engaged in activities related to the resources, are involved and engaged in developing the regime, if possible, and bound by the obligations of the regime once it is established.

Now with regard to the question of broader participation, or some relationship to the international community as a whole, I don't know that we have an answer.

One idea that appeals to me is the idea of building in the right kind -- and I think it was suggested by Mr. Gottschalk earlier -- of building in the right kind of relationship with international institutions that would represent the international community as a whole or which might represent the needs of certain segments of the international community, specifically those which are most in need of -- or could most benefit, let's say, from the large scale development of new sources of protein.

MR. HARGROVE: Well if I may just press this one moment, that doesn't quite answer the question.

The question, more precisely is: Do you expect that you will get to the so-called "decisive meeting" without having any real pressure applied from states falling outside this group to be allowed to crash the party.

MR. SCULLY: Which group do you mean? The group that's other than consultative --

MR. JAMES BARNES: The Group of 77.

MR. HARGROVE: I would assume that the Section III here at least implies that participants in this recommendation had in mind that the group negotiating the final regime would be the consulting parties and those who are engaged in research and exploitation with respect to these resources -- and there has been talk in public fora by people who don't fall into that class, about the concept that this resource might be treated as something the economic grant of which belongs to the international -- members of the international communities ... ought to participate in the negotiating arrangements for the exploitation.

Do you feel that that is a practical problem?

MR. SCULLY: I am not in a position of predicting. It's potentially a problem, obviously.

Again, looking at it from a personal point of view, I think the implications of accepting a premise that in some fashion the international community might claim economic "rent" for resources on what we would consider to be the high seas, that there's some obligation to share that with the international community as a whole -- are interesting.

I don't know whether this probably will arise or not. I would hope that a rational means can be found to solve it.

Rather than having, let's say, a 150 nation negotiation which is going to involve the political decisions on how to run a resource management regime, it might be possible to do something that in my view would be more rational, which would be to build the kind of institutional relationships which would, hopefully, allow for the so-called international community interests to be meshed with so-called conservation interests, into something of the benefit of all. But that might be kind of panglossian.

MR. HARGROVE: Lots of luck.

MR. JAMES BARNES: Yes --

CHAIRMAN BREWSTER: It is an obvious problem, an obvious danger, I don't know how it will eventually come out.

At this juncture, I would like to recess the meeting for fifteen minutes.

We will reconvene at 4:10.

(Proceedings were recessed briefly, after which they resumed as follows:)

CHAIRMAN BREWSTER: Can we reconvene? Is there any further discussion?

MR. KNIGHT: Oh, I guess I can start off. I just have a question of someone which might be conceived of as fairly important, I think. I would like to know what your thought is, or if you have thought about possible public representation on the delegation to Canberra.

I know that -- I think Pat went to the Ninth Meeting --

CHAIRMAN BREWSTER: Yes.

MR. KNIGHT: But I was wondering if you were thinking of having more than one.

CHAIRMAN BREWSTER: Yes, I have thought about it.

I do intend to have more than one and I intend also to again invite Congressional representation.

My thoughts and recommendations are subject to confirmation -- "confirmation" isn't the right word -- the responsibility for final decision rests with another bureau, but I expect to recommend more than one public representative for the delegation.

Are there any further comments or questions?

If not, I would first like to thank you for coming and participating in this meeting, and I hope that if you have additional thoughts or new thoughts, you will communicate them to us.

If you have not registered when you came in, I would appreciate your doing so. That will provide us with a list of people to whom we can send our notices about the second meeting, which I anticipate in February, to discuss the Environmental Impact Statement. I also hope to use the same list to mail to those of you who have been here or otherwise indicated an interest you a report of the Special Consultative Meeting at Canberra.

Thank you, very much.

(Proceedings ended at 4:25 p.m.)

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# APPENDIX C

## Transcript of Public Meeting on the Draft Environmental Impact Statement for a Possible Conservation Regime for Antarctic Living Marine Resources

Department of State

# Transcript of Public Meeting
# on
# Draft Environmental Impact Statement
# for a Possible Regime
# for Conservation of
# Antarctic Living Marine Resources

February 10, 1978

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DEPARTMENT OF STATE

The Open Meeting on the Draft Environmental Impact Statement for a Possible Regime for Conservation of Antarctic Living Marine Resources, conducted by the Bureau of Oceans and International Environmental and Scientific Affairs, Department of State, was convened on Friday, February 10, 1978, at the hour of 2:12 p.m. in Conference Room 1107, New State Building, Washington, D.C. with Deputy Assistant Secretary Robert C. Brewster presiding as Chairman.

THE CHAIRMAN: Good afternoon, ladies and gentlemen. My name is Robert C. Brewster. I'm Deputy Assistant Secretary of State for Oceans and International Environmental and Scientific Affairs.

The purpose of this meeting is to hear your comments and suggestions with respect to the Draft Environmental Impact Statement for a Possible Regime for Conservation of Antarctic Living Marine Resources (EIS), which was published by the Department on February 1.

This hearing represents, in a sense, a departure from the ordinary EIS procedure. The specific purpose of this meeting is to have your suggestions in advance of the final formulation of the U.S. Government position on negotiating the regime. The written comments, in accordance with standard procedures, are not due until mid-March.

I believe you're familiar with the draft of the subject matter, so I will only introduce some of the people who are here to assist in either answering your questions or to hear your suggestions.

Beginning on my right, Dr. Katherine A. Green, biological oceanographer, who has drafted the EIS in large part and who will be a member of the delegation in Canberra.

Mr. R. Tucker Scully, from our Office of Oceans and Fisheries Affairs.

Mr. Theodore Sellin, who is Polar Affairs Officer.

Mr. Alan Ryan of NOAA.

There are also other U.S. Government officials here.

With that I suggest we go directly to your comments or questions.

MR. ROBINSON: Mr. Brewster?

THE CHAIRMAN: Yes?

MR. ROBINSON: My name is John Robinson, of the Center for Law and Social Policy; and my comments are these: It seems to me that any regime is really only as good and only as real as the body that regulates it. And from the draft EIS it's extremely difficult to know a great deal about the regulatory body. We don't know about how much money it's going to have, where the money is going to come from. We don't know just what it's going to regulate or how it's going to regulate it.

We know, for instance, from your discussion of last December -- the previous meeting -- the language of Recommentation IX-2 of the last Consultative Meeting doesn't rule out some kind of meaningful regulation of the way it can be fished, how much can be fished, or when it can be fished. But we don't really know from the draft EIS what you propose to be a minimal acceptable regulatory body.

Secondly, in a related fashion, the draft EIS makes a great deal -- and correctly so -- out of the need for scientific data collection; and yet we don't really know from the draft EIS what the relationship between the scientific data-collecting body and the regulatory body will be.

If, for instance, the regulatory body can control the data-collecting body, there is of course the danger that the data collected will be biased by the regulatory agency's interests. If, however, the scientific body is totally independent of the regulatory body, there's a danger the data will be collected and shot into a void.

We'd also need to know, I think -- since this regime will be, basically, as far as we can tell, a fishery management body -- how this regime is going to differ from other fishery management conventions -- specifically, how it's going to avoid the failures of these previous conventions.

Thirdly -- and I suppose of most concern in terms of any success at all -- is the problem of the less developed nations. As we understand the politics of this regime and of the treaty itself, there's a real pressure that exists on the part of the Group of 77 and the less developed nations as a whole. They're looking for -- anxious for -- a piece of the action, and the Club of 13 that controls Antarctica is quite reluctant to share any of the produce out of whatever kind of living resource harvesting goes on.

We're curious to know what the State Department's position is, independently of jargon phrases, and then to get really strong responses on some profit-sharing either by a rent proposal -- as we suggested on December 20th -- or by capitalizing the ventures of interested Third World nations, or by simply giving a percentage of the catch -- assuming that krill is caught and given to the less developed nations.

These are a few of the concerns the Center and the constitutencies that it represents have initially, and we hope that you could address them now or address them before you go to Canberra, so that the people who do go to Canberra are armed with the information they need to deal with it effectively there.

MR. SCULLY: Let me, if I could, make a few preliminary comments. One of the primary purposes of this meeting is to receive views and to have our attention drawn to areas where the EIS would need some further clarification prior to negotiations.

We may not have all the definitive answers, but I think that if I understand correctly, you raised three points -- one with regard to the lack of clarity with regard to the regulatory body itself, the organizational structure.

I would say that it's probably impossible to be completely specific about what kind of organization, what kind of regulatory body, would come out of the negotiation of this sort. There are probably a number of acceptable alternatives, I don't think there is necessarily one road to Rome in this instance.

It is the United States view that an effective conservation regime, which we have indicated we support, requires an effective organization, an effective regulatory body, to fulfill the purposes of the regime.

With regard to the question in Recommendation IX-2 of what kind of regulations an organization would apply, we hope to write into the Convention an ecosystem approach as the conservation standard.

Thus there should be in the Convention a standard which the organization, whatever its form, will be obligated to follow in developing conservation measures.

There are a number of functions, some listed in the EIS, to be performed by the regulatory body. We would see among these, in applying the conservation standard, the identification of any species or group of species which require measures and then recommendation and development of such measures by the organization. It is our view that the organization should not operate on the basis of unanimity; it should operate on the basis of a qualified majority. The conservation measures should be final and binding.

This leads us into the question of scientific data and of scientific advice. One of the purposes we have always felt would be served by the development of a regime would be to establish a mechanism for acquiring the right kind of data with regard to the Antarctic ecosystem and its marine living resources. This would involve both catch data and statistical data on any harvesting that's going on by nations that are engaged in such harvesting, as well as basic scientific information on the resouces themselves -- and on the ecosystem as a whole.

The regime needs to make provision for the receipt, compilation, and analysis of data. It would include basic scientific data; it would include catch statistics.

On the basis of such data, the regime requires a body for making independent assessments on the basis of objective criteria of the status of any given stocks, the marine living resources in the area, the ecosystem as a whole and the effects upon the ecosystem as a whole, and the stocks of proposed conservation measures.

We don't have a specific answer at this stage of the game as to how that scientific body would be constituted; but it should perform those functions. Further, it should be insulated, as far as possible, from the political decision-making process in the Plenary Body of the Commission, or what we call the Commission itself. We believe it's essential to assure that the Commission -- which will actually formally adopt any conservation measures -- will have as independent scientific advice and as independent assessment of the ecosystem and the components of it, as is possible to provide. That will be the standard we will be seeking to apply in the development of the organizational machinery.

There are a number of possible ways of achieving this objective. To cite two examples: there are a number of fishery conventions with provision for scientific advisory committees in which all participants in the organization, in the regime, have the right to be represented -- to have scientific representatives. That's one example.

Another is the creation of a totally independent body responsible only to the Commission itself, of building a large scientific Secretariat in the body of the organization itself.

It may be possible to combine these two, though in so doing we would wish to avoid duplication of effort. We'd like to see the organization establish the proper kinds of relationships with other scientific bodies -- SCAR, FAO, other bodies that are involved in doing wotk on the ecosystem and its components.

There is no definitive answer on what the organizational structure should be. In our view, there has to be an effective one. We have tried to elaborate this in the EIS. We'll be elaborating further the objectives and the standards which we believe that organizational structure should be. And, of course, we think it should be satisfactorily funded. As to the level of funding, I don't know that one could answer that question now. Again we believe that it has to be funded in such fashion and at such levels that it can carry out the purposes for which it's created. We have no specific answer on that particular item.

With regard to the question of less developed nations, I'm not sure, with regard to Antarctic marine living resources, that I agree that there's a great deal of pressure at this stage of the game. I think there is a basic interest of all nations -- and again I think this has been expressed by developing countries at least in the FAO context -- that no regime be concluded which in principle excludes them from potential harvesting.

With regard to the question of profit-sharing or assistance to developing countries, the United States is probably in somewhat of an anomalous position since we ourselves are not engaged in fishing. We might be considered to be proposing to give away other people's fish catches.

I think that it's probably premature -- and this is a personal view -- to assume that Antarctic krill or other resources which are a part of the Antarctic ecosystem offer the kind of low-cost protein that may be of real benefit to developing countries. I'm just not sure that we can make that assumption.

I would say that it is premature to start considering, in the context of a conservation regime, these kinds of distributive elements -- the question of how the ultimate products may be used and distributed. To do so at this stage of the game might well prevent agreement on the kinds of conservation measures that we believe are necessary. I do think it a valid point, that there should be in principle no exclusion of eventual development of harvesting interests -- development of interests in the resources by any country.

PROF. BUCHSBAUM: I'm Ralph Buchsbaum. I'm a retired professor of biology, specialist in invertebrates and ecology; and I am living now in California.

I'm here for a board meeting of the Defenders of Wildlife.

I'm speaking now as a scientist rather than as a member of any particular group.

I have had an opportunity to look this draft over -- not in great detail but long enough to commend the people that wrote it as being a very reasonable sort of document -- except I'd like to call attention to the possibility of emphasizing something which seems not to be emphasized sufficiently, in my judgment.

First of all, you're dealing with a very cold water and a process -- a biological process -- that's very slow. The temperatures are down close to zero degrees Centigrade or below, and biological events take place at an extremely slow pace. And so any major perturbation on the part of Nature or Man -- well, at least humans -- might result in irreparable damage or the kind of damage you get in the Arctic tundra or on mountain tops.

We do not know sufficiently about how fast the Antarctic ecosystem can recover from abuse or perturbations. This should be mentioned in the report as an item of concern. The term "fragile ecosystem" I wouldn't want to apply necessarily at this stage. But I would predict that "fragile" is an adjective that might well come into this whole scheme. That is the major point.

The second point is more political. It has to do with the principle of the Tragedy of the Commons. Any new area opened up freely to exploitation tends to be overexploited, if it is of any value; and the tendency is: "If I don't get it, somebody else will." And the result is the degradation of that resource.

I don't believe that enough emphasis -- if you don't like that term "Tragedy of the Commons," for whatever reasons -- nevertheless, the concept is valid. And I think that some paragraph ought to be put in to show the reader and the concerned people that this idea is valid in this context. That hasn't been done, in my opinion.

The third point is a small substantive point. On page 16 it says "Species in the Antarctic Marine Ecosystem" -- and nowhere do I find, unless I haven't read it carefully, in the list of animals and in the paragraphs subsequently -- except in the very last under "Whales", "Food Web" -- but generally there's no mention of other animals than the mammals, the birds, krill, squids, and fishes.

You don't have all of the other many worms, sea anemonies, sea stars -- many other creatures that occur in very large form. There are sponges that are seven feet tall and are a thousand years old.

Now, that is like a redwood tree, in a way; and you cant't just go in there and collect those thousand-year-old sponges with immunity to damage of this ecosystem any more than you can go out in California and cut off the redwoods with immunity to the damage of the system.

So I would ask you, if you could -- if you see it right -- to put in a little more on the invertebrates to show that the Committee is aware that there are many more animals than indicated in this present document.

And then I end on a little levity perhaps. The word "whale" is used in the singular. "Whale" in plural is "whales" -- and "bird" and "birds", and "penguin" and "penguins". But when it comes to "krill" it's "krill"; and "squid" is "squid" rather than "squids".

Now a squid is a magnificent animal. It has a personality and should be reckoned with and treated as an individual. So there's one squid and two squids. And if you ever deal with them physically, you know what I'm talking about. (Laughter.)

Now, it is the practice -- it is commonly used among firshermen -- that if you are harvesting something, like grass -- if it has no personal value or humane value in any way and it is a commodity, then it's treated in bulk-- whereas if the individuals are valued as individuals in their own right, then they're given the distinction of being individuals and treated in the plural. So you have "Squid are probably abundant ..." when it actually should be "Squids are abundant..."

Now, it makes not a tremendous difference except the semantic reference. If you keep to a proper plural, then you avoid criticism on the basis of "We regard these animals as a commodity", you see. So when little green men come from outer space they'll speak of "human", not "humans". There are "human" on this planet to be harvested, you see. (Laughter.)

So the point is merely a semantic one. Thank you very much.

THE CHAIRMAN: Thank you. You should come to Washington more often. (Laughter.)

We will take not of your comments in the preparation of the final EIS. I appreciate having them.

Yes.

MS. MITCHELL: My name is Barbara Mitchell. I'm from the International Institute for Environment and Development.

We've prepared a statement with our preliminary comments on the Draft Envioronmental Impact Statement and, if I may, I'll just summarize now and submit the statement.

We feel that as the objectives of the regime are described in the statement they are sound. We are concerned, however, that the means by which the Government hopes to meet them are left too vague.

There seems to be, in effect, a danger that the proposed Government action will result in a regime which is more like the rejected "no-act-now" approaches than the U.S. Government actually intends. In criticizing the latter approach on page 4, the draft EIS describes the drawbacks of the gradualist approach. It refers to "extensive evidence" from efforts to conserve marine resources in other areas of the world, that "after the fact" regulation is not effective. It notes that "initiation of effective regulation would likely be more difficult once substantial economic stakes in uncontrolled methods of harvesting are created".

Now, we have no objection to a degree of flexibility in approaching this task, as long as it is backed up by the strongest textual guarantees in the Convention. Now, some of these will be very difficult to negotiate, but it should be borne in mind that decisions made here will be of the greatest and most lasting importance for the future of what may become the world's major fishery. The following elements of the regime would seem to require further consideration:

First of all, Interim arrangements.

We feel that the immediate introduction of some form of regulation of the fishery is essential. We notice that in the description of proposed federal action on page 6, the draft EIS suggests two ways of dealing with harvesting in the interim period. The first would be to assume that "technological and other limitations will ensure low harvesting levels for the next several years". The second would be to negotiate, as a supplement to the international agreement, very conservative catch limitations, with provisions for phased expansion of that limit.

We fully endorse the statement on page 7 favoring the latter option. Although the latter option would be far more difficult to negotiate, it indeed reflects a more sensible approach to the exploitation of a resource with which there is very little international experience. We hope that this sub-option will be adopted and we hope that it will be fully negotiated before the Convention is signed.

Secondly, the Development of conservation measures.

We feel that the tools of conservation should be spelled out in the Convention. We notice that the proposed federal action would leave the development of specific conservation measures to the decision-making body established under the agreement.

While we do not claim that sufficient information is already available to establish catch limits and other specific conservation measures on a long-term, definitive basis, we do feel that the appropriate decision-making body -- the Commission, in the Government proposal -- should be explicity authorized in the Convention to implement controls in the following areas:

Catch limits for each species, according to

- age or size class
- geographic area
- season

Total catch limits for each species

Allowable gear

Total effort or time spent in harvesting

National catch and effort allocations

Annual increases in national effort and catch.

At the recent meeting in London of the Antarctic Treaty powers, the possibility of catch allocation was excluded. This omission will seriously handicap any attempts at conservation. The U. S. delegation at Canberra should reintroduce the principle of national catch and effort allocation now and ensure that any institutional mechanism established be empowered to raise the issue at a future date.

3. Decision-making.

I'd like to stress as my closing point now in agreeing with the Center that the Draft Environmental Impact Statement, in describing the proposed Government action, does not ensure that economic and other considerations will be prevented from overriding scientific advice in decision-making. Furthermore, we are not given sufficient guarantees as to the impartiality of the scientific advice which will be provided.

We feel that more details are needed on the relationship between the Commission and any standing scientific body. Another question is: "Who will be responsible for the scientific work and how will it be funded?"

Another item on the decision-making is The Commission.

We feel that clarification is required on decision-making in the Commission. Decision-making should be open and all information on which decisions are based should be made available to the public.

Finance.

More details are needed on the projected financial arrangements. We note that the U. S. would support the scientific research necessary to establish conservation policies and that it would expect to contribute a share of the running costs of the organizations. It is vital that the Convention should seek a similar commitment from each contracting party. In particular -- and I stress this -- there must be a guarantee that all research work, including the monitoring of non-target species which might be affected by harvesting but are not of immediate economic interest, be adequately financed on a long-term basis.

Five, Enforcement.

Provision should be made for effective enforcement and policing of any arrangements. We feel that the draft EIS does not make detailed reference to this very important question. The appointment of independent observers and their right to carry out inspections should be written into the Convention. Flexible settlement of dispute provisions should also be included.

Six, Links with the International Whaling Commission and the Convention for the Conservation of Antarctic Seals. Provision should be made in the Convention for full coordination between the activities of these agreements, if the regime is to meet its objective of providing for the "effective conservation of the marine living resources of the Antarctic ecosystem as a whole". We notice that the draft EIS leaves this task -- the establishment of coordination -- to a standing body to be created under the convention. But we feel that the coordination must be provided for in the Convention itself.

Finally, International Community interests.

Steps should be taken to protect the interests of the broader international community in these marine living resources.

We regret to note that the proposed federal action does not address this point. On present indications the regime will provide for no more than freedom of access for those able to develop the resource.

In reference to the point that was made by Mr. Scully earlier, I don't think that it's premature to raise this point now because we recognize that what's being established is a conservation regime. But as the draft EIS notes on page 54, U.S. interests in the conservation of Antarctic marine living resources include the rational development of new sources of protein and the prevention of international conflict over Antarctica as well as a commitment to maintaining the Antarctic environment. If we postpone this issue, it may make it politically impossible to negotiate any proposal to ensure that this source of protein is used to maximum benefit. In order to accommodate these concerns, we feel that three steps should be taken:

- The Convention should include a general provision recognizing the interests of the international community -- or, at least, agreeing not to jeopardize those interest -- along the lines of the recommendation on mineral resources quoted earlier.

- Second, a strong institutional relationship between FAO and the future living resource regime should be written into the Convention. Althouth the proposed federal action anticipates a "close working relationship: with FAO, it again leaves the establishment of this link to a standing body to be created pursuant to the regime.

- Thirdly, we feel that delegates from international organizations, such as the United Nations Food and Agriculture Organization, as well as all krill-fishing nations, should participate in the next meeting held to discuss the regime after Canberra. We understand that it's, indeed, a U.S. goal to invite other parties. But, to make this participation meaningful, options should not be foreclosed in Canberra and Treaty parties should not present "outsiders" at the next meeting with a fait accompli. Furthermore, "outsiders" should have a full voice at this meeting -- the next meeting after Canberra.

So, in short, we feel that a good many elements of the regime should be spelled out in greater detail -- both in the description of proposed federal action, in the U.S. position papers prepared for Canberra, and in the Final Environmental Impact Statement -- and, most importantly, in the Convention itself. We believe that this is the only way to ensure that this important regime is both sound and equitable.

Thank you.

THE CHAIRMAN: Thank you.

MS. SCHARLIN: Pat Scharlin from the Sierra Club.

I won't reiterate what has been mentioned by a few of our speakers up to this point, other than to say that I also feel the Federal Government should pay special attention to the costs involved in such a regime -- especially in view of the rather limited sums of money that appear available. In the case of the International Whaling Commission, if it's to be similar, in view of the difficulties in the Antarctic region, I would think that the sums of money involved would be significant and would probably affect the carrying out of any sensible regime.

We also are concerned about enforcement measures and how that should be spelled out; and, in addition to that, dispute settlement procedures should obviously be built into any final regime to make it effective.

We're also curious to know more about what is meant by coordination with the International Whaling Commission and the sealing Convention and how this particular region would be coordinated with those two.

In particular, we're concerned with the development at the present time of whales as a food resource for the future. In our view, it is a remarkably available resource; and the use of krill, for its own purposes, might have a rather serious effect. Therefore, coordination of those two particular bodies -- that would be particularly important.

Finally, I will mention on this point the problem of implementing any regime, once it's begun -- developed, established -- it will take quite a number of years before the instrument would be ratified. And at the same time, according to the EIS, within 20 years' time, krill could be overexploited. So I think this is another problem that might better be addressed more specifically in terms of what kind of very strong interim measures would be taken so that we could avoid that possibility of exploitation.

THE CHAIRMAN: Thank you.

MR. KAUFMAN: Mr. Chairman, My name is Milton Kaufman. I'm the President of Monitor, Incorporated, a U.S. consortium of environmentalists concerned with conservation and preservation of marine mammals, and President of Monitor International, a revolving consortium of international conservation groups.

I'd like to identify myself with the comments that have been made by the International Institute for Environment and Development and the Institute at the Center for Law and Social Policy and Dr. Buchsbaum's comments.

I might add, in identification of Dr. Buchsbaum, that he is the Chairman of Monitor International's Committee.

I won't repeat the points that have been made by the other speakers in the interests of time. I have one point that I would like to make, which I don't think has been really touched on this afternoon; and that relates to the relationship of the international program of the Marine Mammal Protection Act of 1972 to the evolving United States position we'll be taking in the negotiations on the international regime.

As we read the internal program, the United States is obligated, in any international negotiations that relate to the conservation of marine mammals, to make every effort to build into the evolving international agreement principles of the Marine Mammal Protection Act. And I feel that not adequate attention has been given to that requirement in the EIS.

Many of you are familiar with the Marine Mammal Protection Act. It requires that marine mammals be managed on an ecosystem basis, that population levels be maintained at an optimum state or population level.

I think that the U.S. delegation would have no choice but to support this concept in the development of a U.S. position, the presentation of a U.S. position. This might well be translated in terms of, you know, what we might say to the other negotiating nations -- that we are interested in maintaining all of the species in the Antarctic regime at an optimum yield level.

This is a rough similarity to optimum stable population level but not identical. Certainly I think as far as marine mammals are concerned, I think we're obligated to use the optimum stable population concept prescribed by law.

We will be submitting a detailed, written paper on the EIS. We appreciate the opportunity to be here this afternoon to discuss this.

THE CHAIRMAN: Thank you.

DR. SEGAR: Mr. Ambassador, I'm Doug Segar, representing Congressman Robert L. Leggett's office.

For a point of information of the meeting, yesterday Congressman Forsythe, who is the ranking minority member on the Ad Hoc Select Committee, and Mr. Leggett, co-filed a bill in the House of Representatives, which would set up within the National Oceanic and Atmospheric Administration a new polar fisheries conservation program. This would be a comprehensive conservation program for all aspects of the marine ecosystems -- both the Antarctic and the Arctic polar regional seas.

The bill is a relatively modest one, but we bring together a number of programs that are eventually under the auspices of NOAA and give them the relevant resources to handle its programs. This is in response to the need that we see for a greater focus in the overall ecosystem conservation needs of the two polar regions.

THE CHAIRMAN: Thank you.

MR. ROBINSON: I wonder if I could return to a few points.

It seems that what will be negotiated in Canberra, although it will be described as a conservation regime, will really be a management regime since conservation does not mean no harvesting.

And I don't find in the EIS -- and I think it's really outside of Dr. Green's competence, but you can correct me on that -- just how you construct a fishery management regime that is ecosystem-wide, covers an enormous area, that deals with high levels of ignorance because we don't know what the catch will be.

And I wonder if your office or the Department knows -- or if you have consultants who have worked not so much on the scientific aspects of what the BIOMASS in the Southern sea is like but on the other question of what an adequate management regime is like.

Do you see the difference between the two questions? Can you answer it? Is work being done on a management regime so that when you go to Canberra you and the delegation would really know what it is that you would get if you'd have your druthers absolutely?

MR. SCULLY: If I can try, I'll take a crack at that.

If we assume that that high levels of ignorance were an impediment to this operation, perhaps we wouldn't be doing anything at all. We recognize that we're dealing with an ecosystem in which there are many, many unknowns. I do think we know maybe more than is sometimes thought. One of the things that I found in Dr. Green's work is the volume of material that is available, and that good scientific studies done in this area are more extensive than I had thought.

All the same there are enormous unknowns dealing with the Antarctic marine ecosystem; but we do know enough, I think, to have led us to the conclusion that uncontrolled harvesting in that ecosystem poses a danger to the health of the ecosystem. I'm not sure how one would define health in the sense, but let's say in terms, of the ability of that ecosystem to maintain long-term productivity, to maintain the relationship between its components in a dynamic way.

Therefore, one of the things that has led us to try to seek an international conservation regime is to set up a framework which will, first of all, commit the participants in it to conduct their activities in such fashion as to avoid what we see are the possible dangers.

Now, this essentially is a qualitative step. A commitment to a standard. It is not a management plan. It is nothing more than a commitment to apply a standard.

The standard we seek to apply and hope to seek agreement on is an ecosystem standard -- a commitment, if you will, that the system would be managed on this basis. I think that what we're trying to do at this stage is to achieve the framework -- establish a framework, an effective framework -- which then will apply standards we believe would protect the ecosystem, in the long run. And then as information is gathered, as levels of harvesting perhaps begin to increase, there will be the mechanism in place that can control them in proper fashion.

One of the things that we seek in a conservation regime is an international body which will be able to develop management programs. This will in turn require, means for collecting, collating and analyzing scientific data, catch data and all the rest of it.

So I guess I would say in answer to your question: Yes, we do see very much the distinction between a conservation regime and, let's say, actual management plan.

We think that the first step one has to take, to establish the regime, is to bind all of those who are involved in potential activities -- to devise management plans when they're necessary, and to set forth the criteria on which those management plans would be developed.

I'm not sure whether we're in a position to predict what those management plans would involve. We would argue that they would have to involve the full range of conservation techniques as we understand them -- although I would not want to see written into the Convention anything that's purported to be an exhaustive list which might limit the regime's ability to meet new circumstances.

I don't know whether that answers your question. It seems to me that it is not possible at this particular point in time to devise a detailed management plan to deal with this ecosystem or with any major component subject. What we want to do is to create a system that makes it possible to do so prior to the time at which any large-scale activities take place.

MR. ROBINSON: Well, I appreciate your dilemma. Oddly enough, it's a result almost of your virtue (laughter) -- that is, in clueing in the rest of the world on the fact that the State Department is moving towards a regime. You're having to meet with us prior to having definitive plans of all different sorts made up -- especially since the regime that you're heading towards is itself the first step on the road.

There's a further lack of specificity of what it is that you're proposing.

I think that the concern of the Center and many of these environmental groups is twofold. First of all, things are vague and we really don't know what it is that will come out of Canberra. Secondly, we do have a fear -- which Barbara Mitchell, I suppose, voiced most explicitly -- that it will be too diplomatic. That is, one step at a time is how you get places; but if this step becomes the only step -- that is, if this is the only obligation imposed upon harvesting nations -- that is what comes out of Canberra. And if it's a long way down the road, as Ms. Scharlin mentioned, great harm could be done but also great over-capitalization could result; and that would impost almost inexorable pressure on whatever kind of plenipotentiary body you have to give in. That is, if there's a capacity to fish for 50 million tons of krill a year, in the year 2000 it's bad for the whales and bad for the penguins, and so forth, and the capacity will create the obligation. And our concern is that at Canberra -- which is the first step; it could be a large step -- that it be really clear to all the signatory parties that we aren't going to allow that kind of pressure to build up over time.

I think that Machiavelli was kind or right. People do deal from self-interest. And it may appear right now to nations that are harvesting that no interest of theirs is served by restraint.

But I should think that one thing that our delegation could do, because we aren't harvesting, is to point out to folks who are that there is an audience -- there are a hundred and twenty-five nations looking on with more or less interest right now -- in that protein source. And if the people who can afford to and who are interested in harvesting there and for the rest of the century don't manage the resource conscientiously -- not to mention equitably -- in the long run they'll be losers. My fear is that it will be too diplomatic and too vague, demand too little and get even less.

THE CHAIRMAN: I wouldn't write the negotiation off before it's begun.

MR. ROBINSON: No, no.

MR. KAUFMANN: I totally support the comments that John just made. I've been intimately associated with the international problem of tuna conditions for three years in the U.S. delegation, and there we see the same thing that we're concerned may very well happen unless we can build the specificity and control that we need in the Antarctic.

Each year additional ships come into the international fleet to fish for tuna. Each year special allocations, special quotas are given to nations that increase their tonnage of fishing. Each year, empirically, the Commission staff of the IATTC says, "Let's try a greater tonnage than last year and see how it works." This is the way they scientifically manage the stock.

Now, I think we must come to grips in developing our U.S. position with the problem of limited entry into the fishery.

It's my understanding, although I'm not an expert in this matter, that there isn't any successful example in international fishery of limited entry. But I think we've got to address this problem and put a great deal of effort in developing a U.S. position that will set a ceiling on annual harvest and on the capacity of the harvesters in terms of the vehicles they use to achieve the harvest.

So I strongly support John's position. We have exactly the same experience with the International Whaling Commission. As some people in the room know who have been a party to the delegation and observers to the IWC, for years it was not a conservation regime; it was a club of whalers. And the problem was management -- "How do you slice up the pie, boys?" -- not "How do you control the take properly?" so that the species would go on and not be threatened.

So we're at the stage now where I think we must come to grips with this problem and try to come up with the answers.

MR. HOFFMANN: My name is Thomas Hoffmann. I'm also from the International Institute for Environment and Development. And I would like to return to one of the issues that was first raised by John Robinson in his statement and reiterated by Barbara Mitchell when she outlined our organization's views, and that's this question of whether or not raising the long-range issues of distributing krill for the benefit of the developing world has anything to do with the conservation regime -- and whether or not it's better to raise those issues now or to let them percolate in the hopes that a discussion of them would avoid jeopardizing the negotiation.

I think two points have been missed. One thing that Mr. Scully said, I confess, disturbed me a little bit. One of the three reasons that he gave as to why it was premature to raise the issue now was that, in response to Mr. Robinson, there was not yet pressure from developing countries -- that was stating the case too strongly.

It seems to me that it is clearly the public position of the Carter Administration that national aid policies, national policies about economic development in the Third World, have nothing to do with international beneficence; they have to do with the long-range perception of U.S. self-interest. He outlined that in his speech at the University of Notre Dame; and I think that that perception should guide what we do, not the perception of the great giveaway.

But second, and much more importantly, it's not a question of international beneficence. I'd like to posit just as a hypothetical the kind of thing that could happen if the Convention takes no account of this issue at all.

But suppose, as it seems likely, it takes six or seven years to bring the Convention into force -- or it seems possible perhaps; "likely" may be too strong a world -- and suppose that in that time krill does become a major fishing resource. A country like Brazil, which is not a party to the Antarctic Treaty and has the economic wherewithal to develop a long-range fishing fleet which it doesn't now have, might become very interested in the resource. It might develop a fishing fleet. It's not that far away from Antarctica. And it might get involved down there very heavily, for example; and then you'd have a country that's not a part of the Treaty; and it would be in a competitive situation with a country that is a party to the Treaty interested in fishing and probably not all that interested in conservation. (Ed. Note: Brazil acceded to the Antarctic Treary on May 16, 1975)

I'm not saying it's going to happen; I'm saying it could happen.

It's the same kind of situation where we weren't too concerned 10 o 15 years ago about developing countries being party to the Non-Proliferation Treaty -- although we welcomed their signing the Treaty. And now what's happened is that we've run into tremendous nuclear-safeguards problems in those countires that import nuclear fuels and aren't a part to the Treaty so we can't implement safeguards.

And I really do think that that kind of hypothetical might be, I suppose -- well, I don't think it's far-fetched and won't say it is. It could happen. So I think these things have to be thought about now.

Second, I think -- let me just restate the obvious, which is that the U.S. does have a commercial interest now so it is in a position to do something.

And, third, I want to answer one other of Mr. Scully's points, which was that we might look like we were giving away other people's resouces. I agree with that. I think that's a valid point. And I think what we have to do is preempt that issue by making it clear that that wouldn't be what we were talking about, that the Antarctic -- the other Treaty powers -- would not feel threatened by the U.S. articulating some policy on this issue because it would be clear that we weren't talking about the great giveaway but maybe talking about international development assistance, to help develop through the World Bank or some form like that -- helping developing countries establish long-range fishing fleets.

And if you don't build that in now, as I said with my Brazil hypothetical, if and when they develop a fleet it would be very hard to get them into the Treaty because the so-called environment/development tradeoffs are always tough for developing countries. And if in 10 years the developing country develops a fishing capacity and isn't in the Convention, it's going to be pretty tough going to get them in then.

THE CHAIRMAN: It's going to be tough going to get them in now if we write into the proposed Convention things which they're unable to agree with: don't forget that the potential signatories to the Convention are not totally without other resources.

MR. HOFFMANN: I'm afraid I don't understand your point.

THE CHAIRMAN: Absent a Convention, countries which are planning to harvest can go ahead and harvest.

MR. HOFFMANN: Sure. I'm not saying jeopardize the negotiation of a conservation regime in order to achieve this subsidiary, and admittedly subsidiary, point that I've been talking about. I'm simply saying it is more of a problem than the attention that's been given to it indicates.

MR. SCULLY: If I might just add a point in response, or at least in comment, it seems to me that there may be some confusion in your remarks between participation in the Antarctic Treaty and participation in the regime. It is our view that participation in the regime to conserve Antarctic living marine resources should not be limited to members, to consultative parties, or even to acceding parties to the Antarctic Treaty. It should be open to any state that is involved in the activities covered -- essentially, fishing activities.

Therefore, to take the case of Brazil, and I'm quite sure I see the analogy; but it would be our hope that a regime could be designed to which Brazil would adhere to at such time as it began to undertake fishing activities in the area.

To go back to the question of distributive elements, I think what bothers me to a certain extent is an assumption -- an automatic assumption, which I think I hear, that krill will solve world food problems or will solve developing-country problems with regard to protein deficiencies. I'm not sure that's true. I'm not sure we're in a position to say that's true and to start negotiating on the basis of the fact that it is true. Krill may offer only a very high-cost protein for certain end uses. It may be that krill -- krills -- will not compete favorably with other forms of fishmeal, for instance, or with various kinds of vegetable protein sources -- soybeans or whatever -- if it's being used as an animal feed or something of that sort.

My reaction is that I don't know whether one should seek to establish or to rely upon Antarctic marine living resources as a major element in anybody's development strategy. We can't make that decision now. I would hope that the Convention will neither preclude that nor end up losing its conservation effectiveness by seeking incorporation of elements that are premature.

I would certainly hope that if it turns out that krill offers an important source of low-cost protein that protein would be applied to world food needs in some rational way.

We can't make that assumption yet and we can't write that into a Convention yet. I would not like to see a Convention which in any way precluded that or in any way asserted any kind of exclusivity with regard to the question of resources being limited to x number of countries.

Finally, let me close by saying that there are just a number of legal questions, juridical questions, raised by the point of assuming that resources in what we would consider to be high seas automatically have a common heritage kind of component.

MS. MITCHELL: May I make one point? I don't think you need to proceed -- or I don't think we're proceeding or suggesting that you proceed -- on the assumption that krill will have great potential for the developing countries. We just feel that it's necessary now to leave the door open to the use of krill later on for developing countries; and we feel that by not stating it in the Convention, however general a provision it may be, you are in fact precluding the option, because investment decisions are being made and capabilities are being built up -- plans are being laid -- and it will be much harder later on to introduce any form of accommodation in the interests of the international community.

THE CHAIRMAN: I don't understand your comments. Would you rather be more precise in an action that you desire that we undertake now? I would associate myself with Mr. Scully's views. I mentioned when we discussed this question before that I had no problem in leaving the Convention open to that kind of an arrangement, should it be decided upon later. But I personally had difficulty with the idea of bringing it forward now as a negotiating idea. I certainly do not preclude, and would personally favor, something equivalent to that part of Recommendation IX-1 which sets the stage for it and would allow it later.

MS. MITCHELL: No, we're not suggesting that it be negotiated now. We're suggesting that the possibility should be provided.

THE CHAIRMAN: That causes me no problem. I just don't want to have to say that certain language is inserted specifically "for the purpose of". (Laughter)

Any other comments?

MS. DONNELLAN: On page 11 in the IES -- 10 and 11 -- are references to the various conventions that do relate to the Southern Ocean area or could. Would it be possible -- if I ask a foolish question -- somehow to include in the regime the means of urging ratification of particularly the pollution foolish type of conventions by signatories to the conservation regime -- somehow put into it some kind of wording that would put a bit of obligation on the part of the signatory states? These conventions are not ratified, they are not in force, and with increased activity in the area it might be important.

THE CHAIRMAN: Yes.

MR. SCULLY: I think in a hortatory sense, yes. You're not going to write a Convention that's going to have the affect, by its ratification, of bringing in force other conventions, but I think that certainly there will be preambular language which would be appropriate for references to other international agreements, the desirability of their coming into force. In this area, however, we may not be in a position to cast too many stones. (Laughter)

THE CHAIRMAN: We're not in the best shape that we could be on these agreements outselves.

Other comments: Yes.

MR. HOFFMANN: Maybe in closing -- I realize you might not want to answer this directly on the public record, but could you respond to Mr. Robinson's observation that you might make the negotiation process difficult by the openness of the EIS processes -- what effect it might have on the negotiations, for example, in other countries that might lay their hands on the draft EIS?

THE CHAIRMAN: I think it would be a help to the United States in the negotiations for others to see that the issues with which we're dealing have been widely discussed and that we have testified before the Congress on them. Indeed, I have already made the point in a diplomatic exchange that a particular U.S. view has in fact been publicly endorsed by the United States Executive Branch. I view this public meeting in the same way -- that the attention that's given to the Antarctic Treaty and Antarctic issues is good. So I don't feel it will be a problem in the negotiations.

MR. BARNES: Mr. Ambassador, I'm Chaplin Barnes of the National Audubon Society. I find myself in agreement with most of what's been said this afternoon; but I just wonder, as a final point: We spent a lot of time discussing the potential and exploitation of the krill, and we're at the point of negotiating this regime basically because some countries are at a point of cmmercial development of krill. We're responding to exploitation pressures.

I hope very much that the U.S. delegation will write into the Treaty its basic purpose -- which is, in fact, to conserve the Antarctic ecosystem. This is the overriding purpose, and this is seen to be so in the document that you'd come back from Canberra with. I think it's very easy to lost sight of that in the details of the exploitation, limits, and so forth.

THE CHAIRMAN: That's certainly our intention.

If there are no other comments, the meeting is adjourned.

(Whereupon, at 3:16 p.m. the meetng was adjourned)

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# APPENDIX D

## Interim Report of the Second Special Antarctic Treaty Consultative Meeting at Canberra and Press Release of the Meeting

ANTARCTIC TREATY
SPECIAL CONSULTATIVE MEETING

ДОГОВОР ОБ АНТАРКТИКЕ
СПЕЦИАЛЬНОЕ КОНСУЛЬТАТИВНОЕ СОВЕЩАНИЕ

CANBERRA

TRAITÉ SUR L'ANTARCTIQUE
RÉUNION CONSULTATIVE SPÉCIALE

TRATADO ANTARCTICO
REUNION CONSULTIVA ESPECIAL

16 March 1978

## INTERIM REPORT OF THE SECOND SPECIAL ANTARCTIC TREATY CONSULTATIVE MEETING

1. In accordance with the provisions of Article IX of the Antarctic Treaty, representatives of the Consultative Parties (Argentina, Australia, Belgium, Chile, France, Japan, New Zealand, Norway, Poland, the Republic of South Africa, the Union of Soviet Socialist Republics, the United Kingdom of Great Britain and Northern Ireland, and the United States of America) met in Canberra from 27 February to 16 March 1978 to consult together and consider measures which might be taken to further the principles and purposes of the Treaty and, where appropriate, make recommendations to their Governments. Specifically pursuant to Recommendation IX(2) of the Ninth Consultative Meeting, they met to elaborate a draft definitive regime for the Conservation of Antarctic Marine Living Resources.

2. The Meeting was formally opened by the Honourable Andrew Peacock, M.P., Australian Minister for Foreign Affairs.

3. Mr J.R. Rowland, Representative of Australia, was elected Chairman of the Special Consultative Meeting. Mr R.H. Wyndham of the Australian Department of Foreign Affairs was appointed Secretary-General and Mr R.L. Moncur of the Australian Department of Science was appointed Assistant Secretary-General.

4. The Opening Session was held in public. Opening statements were made by the Heads of Delegations (see Annex).

5. The Meeting adopted the following Agenda :

(1) Opening of Meeting
(2) Election of Officers
(3) Opening Statements
(4) Adoption of Agenda
(5) Elaboration of a draft definitive regime for the conservation of Antarctic marine living resources taking into account all the points listed in Recommendation IX-2 , Section III
(6) Consideration of steps in connection with the work of the decisive meeting for the establishment of the definitive regime in Recommendation IX-2 , Section III
(7) Adoption of Final Report
(8) Closure of Meeting.

6. The Meeting considered in Plenary Session the first five items on the Agenda and appointed a Working Group, under the Chairmanship of the Representative of the United Kingdom, Sir Donald Logan, to consider the scope of the Convention to be elaborated, including the definition of the marine living resources of the area to which the Convention would apply.

## Elaboration of a Draft Definitive Regime

7. The Consultative Meeting discussed this item on the basis of eight draft Conventions and a number of working papers submitted by delegations and of the report and Recommendation IX-2 of the Ninth Antarctic Treaty Consultative Meeting held in London in September/October 1977.

8. After a full discussion of all aspects of the subject, the Meeting decided to ask the Chairman to prepare an informal text as a basis for its further work.

9. As a result of detailed discussions of this text, the Representatives considered that it would provide a single text that would serve as a basis for further negotiation and decided to refer it to their Governments for study. They agreed that they would then continue their discussions and complete consideration of the Agenda at a resumed session of this Second Special Consultative Meeting. In this connection they welcomed the invitation of the Government of Argentina to meet for this purpose in Buenos Aires in July, 1978.

10. The Representatives recalled the recommendation of the Ninth Consultative Meeting that a definitive regime should be concluded before the end of 1978 and felt that they had made very real progress to that end.

DEPARTMENT OF
FOREIGN
AFFAIRS

NEWS RELEASE

[illegible]

**NO** D8 **DATE** 16 March 1978

## ANTARCTIC MEETING

The Special Antarctic Treaty Consultative Meeting was held in Canberra from 27 February to 16 March. Attached is the press statement released by the Meeting after the final session on 16 March.

D-5

ANTARCTIC TREATY
SPECIAL CONSULTATIVE MEETING

ДОГОВОР ОБ АНТАРКТИКЕ
СПЕЦИАЛЬНОЕ КОНСУЛЬТАТИВНОЕ СОВЕЩАНИЕ

TRAITÉ SUR L'ANTARCTIQUE
RÉUNION CONSULTATIVE SPÉCIALE

TRATADO ANTARCTICO
REUNION CONSULTIVA ESPECIAL

CANBERRA

## PRESS STATEMENT

The first session of the Second Special Antarctic Treaty Consultative Meeting, which concluded in Canberra on 16 March, made very useful progress towards the elaboration of a draft definitive regime for Antarctic marine living resources. The main accomplishment of the Meeting was the production of an informal text which will be used as a basis for further negotiations at a resumed session of the meeting later this year.

Drawing attention to the increasing interest being shown in the living resources found in Antarctic waters, the Meeting stressed the importance of such an agreement. The thirteen Consultative Parties - being those countries primarily interested in the Antarctic - had the main responsibility for the protection and preservation of the Antarctic and its living resources. In the 19 years since the Antarctic Treaty was signed, they had already taken a number of measures within the Treaty framework for the conservation and protection of Antarctic flora and fauna. They renewed their commitment to establish a definitive international regime for the conservation of Antarctic marine living resources before the end of 1978.

A considerable number of proposals were examined at the Meeting, including the texts of a number of draft Conventions. These formed the basis of its work. The Chairman of the Meeting (Mr J.R. Rowland, Deputy Secretary of the Department of Foreign Affairs) tabled a single informal text reflecting the Chairman's assessment of the main elements in the various approaches suggested. This document was revised in the course of the Meeting to reflect trends which emerged as the discussions proceeded.

The discussions revealed much common ground in the positions of the Consultative Parties and a common agreement that a Commission on the Conservation of Antarctic Marine Living Resources should be established. There was a wide measure of agreement on the functions of such a body.

A common element in the positions of delegations was the need for the Convention to contain a number of agreed principles of conservation which should be applied by the Commission. It was also recognised that in carrying out its function the Commission would require the support of a Scientific Committee which would be a source of informed and objective advice to the Commission.

There was also agreement that the Convention should reflect close links with the Antarctic Treaty. There would be a need to harmonise the activities of the Commission in the field of conservation of marine living resources with the responsibilities of the Antarctic Treaty Consultative Parties for the protection and preservation of the Antarctic environment. It would also be necessary to take account of other relevant international agreements and of international organisations such as FAO, whose co-operation would be important.

Work still remains to be done on important aspects of the regime and in preparation for a decisive meeting to adopt a Convention. The meeting welcomed the invitation of the Government of Argentina for the session to continue its work at a resumed session in Buenos Aires in July. The Australian Representative extended an invitation on behalf of the Australian Government to host at an appropriate stage a definitive meeting to adopt the Convention.

# APPENDIX E

# Role of Krill in the Antarctic Marine Ecosystem

APPENDIX E

# ROLE OF KRILL IN THE ANTARCTIC MARINE ECOSYSTEM

by

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## EXECUTIVE SUMMARY

The Antarctic marine ecosystem is considered to be all waters south of the Antarctic Convergence with all the plants and animals living there. The ecosystem is defined biologically by the distribution of *Euphausia superba* (krill), some phytoplankton, penguins, and fish, and seals which are circumpolar but restricted south of the Convergence. Other species, most importantly whales but also some fish, birds, and perhaps cephalopods, migrate across the Convergence providing a link with other ecosystems. The Antarctic ecosystem is defined physically through the boundary of the Convergence, circumpolar upwelling and input of nutrients, transport by the Circumpolar Current, a uniform low temperature, fluctuating pack ice area, and the polar light regime.

Most of the primary production is accomplished by phytoplankton, one celled plants. Algae in sea ice and some seaweeds also contribute. Krill are the dominant herbivore. Krill have an unusual ecological role since they are the main prey for fish, squid, Adelie penguins, fur, crabeater, and leopard seals, and baleen whales (fin, sei, blue, humpback, and minke whales). Other carnivores in the system not feeding on krill are toothed whales (sperm, killer, and some small whales) and elephant seals. Ross seals, Weddell seals, and some fish eat krill incidentally.

Sei, minke, sperm and a few killer whales are now harvested in Antarctic waters. Several fish species are taken in commercial quantities. Squid, birds, and crabeater seals are not now harvested, but are potential commercial resources.

The earliest estimates of production in Antarctic waters were made in coastal areas or at the pack ice edge, the most productive regions. Extrapolating those values to the whole southern ocean area produced unrealistically high values, giving the false impression that Antarctic waters were far more productive than other oceans. On the basis of later measurements in open ocean waters which are more representative of the area overall, estimates of total annual productivity have been revised downward.

Although total annual plant production is not significantly greater in Antarctic waters than in other ocean areas, concentration in a short intense growing season and at the edge of moving pack ice makes production appear very large. Unusually short food chains allow a greater proportion of annual production to be transferred to carnivores, thus supporting very high standing stocks of mammals and birds.

The ecological role of krill is unique. Krill have a longer life span than other marine zooplankton, requiring several years to reach sexual maturity. One species predominantly, E. superba, supports many different predators in five major groups, fish, squid, birds, seals, and whales.

The dependence of many predators on krill as the main food resource implies that overexploitation of krill will be very damaging to most other populations within the ecosystem as well. If krill populations are reduced to the same extent that whale populations have been, then the other potentially harvestable resources will also become scarce. Because krill have a central place in the Antarctic marine food web, excessive harvesting would be dangerous to the entire system.

The reliability of data on standing stocks of various Antarctic populations varies. The extremes of the food chain, mammals and plants, are the best known. Primary production averages about 25 gC/m$^2$/year or 9500 x 10$^6$ metric tons wet weight of plants produced annually. This productivity estimate is consistent with krill standing stock of 200 - 600 x 10$^6$ tons and an annual krill production of 350 - 400 x 10$^6$ tons. Krill population estimates are not based on direct sampling data, but instead are inferred from estimated predation on krill. Good quantitative estimates of krill abundance are not available, in spite of great scientific and commercial interest, but are needed.

Direct estimates of fish and squid stocks are not available. Again population estimates are inferred from predation estimates, and are not reliable figures. The estimates of 14 x 10$^6$ tons for fish and 12 x 10$^6$ tons for squid in this report are speculative. Squid are probably underestimated.

A standing stock of 0.27 x 10$^6$ tons of birds, mostly Adelie penguins, is a good estimate for Antarctic waters. Estimated populations of 5.5 x 10$^6$ tons of crabeater seals (25 million individuals) and 1.1 x 10$^6$ tons for all other seals combined are reliable. Estimated whale stocks derive from fishing data and are very reliable. Current stock estimates for whales are 4 x 10$^6$ tons fin, 1.4 x 10$^6$ tons minke, 0.8 x 10$^6$ tons blue, 0.7 x 10$^6$ tons sei, 0.08 x 10$^6$ tons humpback, and 1.16 x 10$^6$ tons sperm whales.

Estimated annual predation on krill amounts to some 330 x 10$^6$ tons. Crabeater seals account for over 100 x 10$^6$ tons of the total. Squid may consume almost as much. Present baleen whales stocks take only about 43 x 10$^6$ tons.

A commercial harvest of krill would compete with predators. Krill harvested will come from the 330 x 10$^6$

tons estimated consumption, not from some hypothetical unused portion of the population. Potential harvest estimates range from 70 to 150 x $10^6$ tons annually. A harvest at the higher end of that range would displace half of the predators, causing large changes in the Antarctic ecosystem. From an ecosystem perspective, a smaller sustainable yield, say 30 - 60 x $10^6$ tons, seems more reasonable.

It is difficult to calculate potential krill harvest from productivity of the stock itself because of uncertainties in the life span and development rates of krill. Whether the circumpolar krill population consists of one or several distinct breeding stocks is also unknown.

Management and conservation concerns on a krill harvest from an ecosystem standpoint are a possible reduction in the rate of recovery of baleen whale stocks and limitation of eventual population totals, reduction in abundance of other potentially harvestable populations such as fish, squid and seals, and alteration of the trophic structure of the Antarctic marine ecosystem in the event of overexploitation because of the central position of krill in the food web.

A controlled harvest of krill can provide some essential data on krill population parameters and the response of the rest of the ecosystem to changing krill abundance. In addition to usual catch and effort fishery data, nutrients, plant productivity, and populations of krill predators should be monitored.

## INTRODUCTION

Reviews of zoogeography of the southern ocean identify the Antarctic Convergence as the northern boundary of the Antarctic Zone (Broch, 1961; Knox, 1968; Hedgpeth, 1969, 1970). Waters north of the Convergence are in the Subantarctic region. Some species of phytoplankton such as *chaetoceros flexuosus* Mangin or *fragilariopsis sublinearis* (van Heurck) Heiden are only found in the Antarctic zone (Hasle, 1968). The krill *Euphausia superba* are only found south of the Convergence (Marr, 1962). Antarctic seals and penguins probably do not migrate across the Convergence. Some fish and most whales do cross the Convergence to feed in the Antarctic every year. The Antarctic marine ecosystem is defined biologically by the species found in the Antarctic zone.

The Antarctic marine ecosystem is also defined by physical oceanographic conditions which strongly affect its biology. The Antarctic Convergence is a physical feature. Seasonal changes in available light and extent of ice cover are characteristic of the Antarctic zone. The Circumpolar Current serves to connect waters south of the Convergence into a single system through transport of nutrients and plankton.

## QUALITATIVE ECOSYSTEM DESCRIPTION

A conceptual model diagram of the Antarctic marine ecosystem is presented in Figure 1. Boxes indicate ecosystem components. Any organism found south of the Convergence can be placed into one of the compartments. Dissolved organic and inorganic nutrients and organic detritus are also included. These nonliving components are nutrient pools necessary to complete the nutrient cycles.

In Figure 1, box size is not related to total standing stocks of the compartments. Quantitative estimates of standing stocks are given in Figure 3.

Arrows show material exchange and trophic (feeding) flows among ecosystem components. The dark arrows represent pathways with the largest annual total flows. They also indicate the most important predator-prey relationships.

Nutrients enter the system through upwelling. They are lost through Antarctic Bottom Water formation, through sinking to the sediments, and through harvest or emigration of animals. Broken arrows represent the contribution of dead organisms to organic detritus.

### Plants

Phytoplankton provide 80 to 90% of the primary production, or carbon fixation, in Antarctic waters (El-Sayed, 1970; Green, 1975). Phytoplankton are single celled plants. Dominant Antarctic species are diatoms (Holm-Hansen, et al., 1977). Other plants in the ecosystem are algae growing in the bottom layer of one-year sea ice which may provide 10 to 15% of annual primary production (Bunt, 1963, 1968, 1971) and some seaweeds (BIOMASS, 1977).

### Krill

Krill are euphausiid crustaceans which are eaten by baleen whales. They are classified as zooplankton or micronekton. The main species are *Euphausia superba*, *E. crystallorophias*, and *Thysanoessa macrura* (Nemoto, 1959). From the Antarctic Convergence south, the predominant krill species is *Euphausia superba* (Marr, 1962). *Euphausia superba* is the only krill species of commercial interest.

Krill play a very important role in the dynamics of the Antarctic marine ecosystem. They are the main herbivore. With zooplankton, they facilitate nutrient

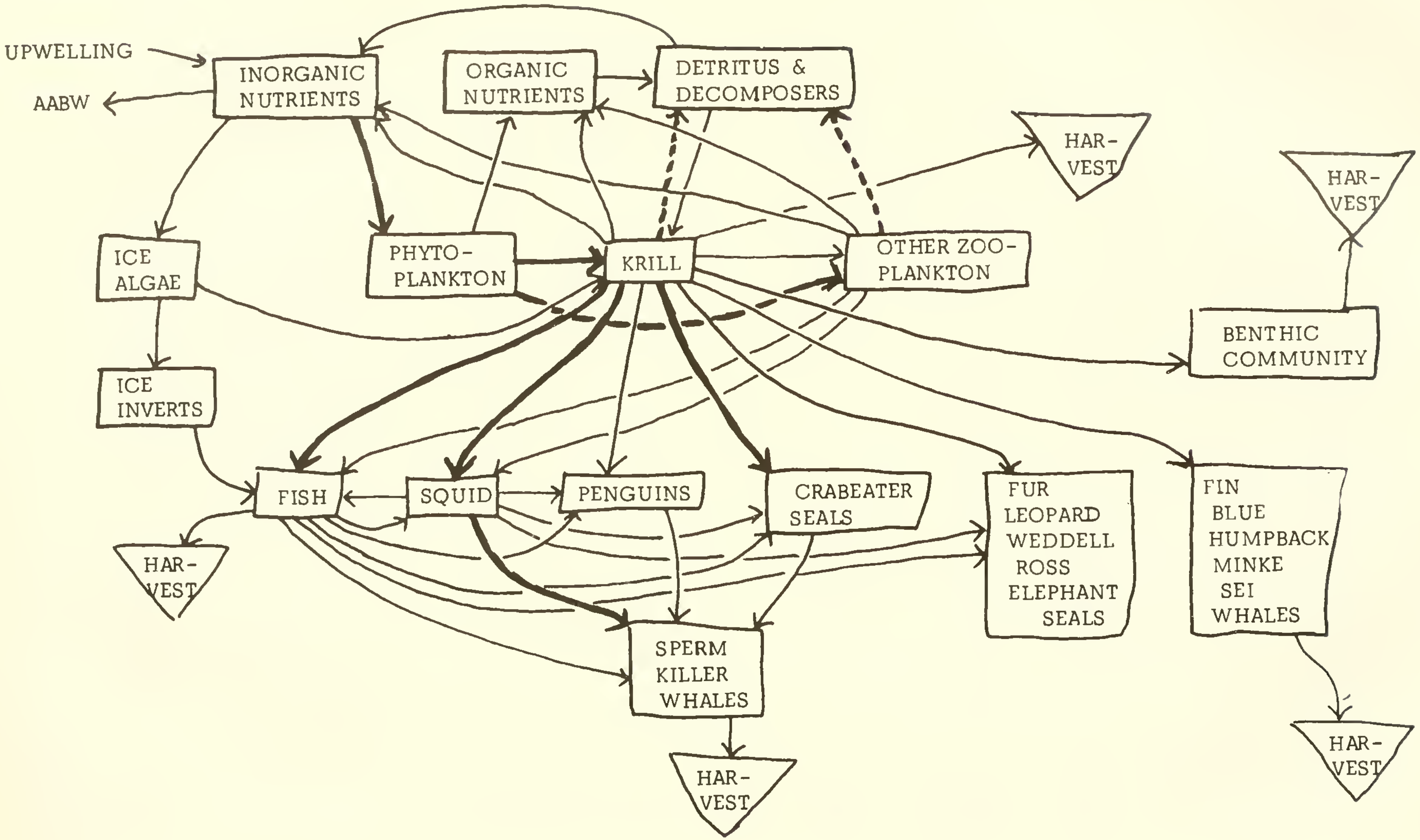

Figure 1. Conceptual model of the southern ocean marine ecosystem

regeneration in the euphotic zone during the growing season. Plankton release organic and inorganic nutrients. Organics are decomposed into inorganics which are necessary for plant growth. Although upwelling brings massive amounts of nutrients into the whole Antarctic ecosystem (Gordon, 1971), regeneration in the euphotic zone during the spring is still apparently necessary to account for the high observed levels of plant growth (Green, 1975). Krill provide the main food resource for fish, cephalopods, penguins, crabeater seals, leopard seals, and baleen whales (Permitin and Tarverdiyeva, 1972; Laws, 1977; Prevost, in press). Because krill are concentrated in swarms, large animals can catch enough to feed themselves adequately. The swarming habit also makes harvesting feasible. The main consumers of krill are crabeater seals and cephalopods (Green, 1977).

## Other Zooplankton

Copepods, amphipods, and chaetognaths dominate zooplankton in the Pacific sector (Hopkins, 1971). In the Antarctic ecosystem as a whole, other zooplankton may be equal or greater in biomass to krill (Gulland, 1970). Although other zooplankton may be as abundant as krill, they are apparently not used as extensively by predators. The disproportionate feeding on krill is indicated in Figure 1, and is more striking from quantitative feeding estimates in Figure 2. This apparent under-utilization of non-krill zooplankton may be an artifact due to ignorance of some aspects of Antarctic ecology. However, it is possible that the dispersed distribution of other zooplankton, contrasted with krill swarms, makes them less accessible to consumers.

## Ice Invertebrates

Invertebrates associated with the sea ice algae community are mainly amphipods (Andriashev, 1968) which are eaten by fish fry (Knox, 1970).

## Birds

Over 95% of the bird biomass in the Antarctic is penguins. South of the Convergence, penguin populations are dominated by Adelies, *Pygoscelis adeliae*, whose diet is mainly krill (Prevost, in press).

## Fish and Cephalopods

Cephalopods in the southern ocean are primarily squid. They constitute significant portions of the diets of sperm whales, seals, penguins, and some fish. It is possible that they are less abundant in Antarctic than in subantarctic areas (BIOMASS, 1977).

Fish species thought to be of greatest importance in the southern ocean are listed in Table 1. At present, fish are not thought to contribute significantly to the Antarctic marine ecosystem (BIOMASS, 1977). Some Antarctic fish species are residents which remain south of the Convergence. Some such as *Notothenia magellanica* and *Dissostichus eleginoides* occur in both subantarctic and Antarctic regions. Information to determine whether these species migrate across the Convergence or form separate stocks in the two regions is not yet available (H. DeWitt, conversation of 15 November 1977). However, it is unlikely that these are of commercial interest.

The blue whiting *Micromesistius australis* does migrate across the Convergence and is harvested.

## Seals

Crabeater seals are by far the most abundant species in Antarctic waters (Erickson, et al., 1971; Laws, 1977). Other seals present in the system are fur, leopard, Weddell, Ross and elephant seals (see Table 2). The crabeater, Weddell, leopard and Ross seals inhabit the pack-ice zone. The fur seal *Arctocephalus gazella* breeds on islands south of the Antarctic Convergence, primarily South Georgia (BIOMASS, 1977). The crabeater seal consumes mainly krill. Other seals eat fish, cephalopods, and occasionally birds and young seals.

## Whales

Antarctic whales feed intensively in Antarctic waters in the summer months, increasing about 50% in weight. After migrating northward in the autumn, they feed relatively little during the winter. Large baleen whales feeding south of the Convergence are fin, blue, sei, humpback and minke whales. Sperm whales, killer whales, and some smaller toothed whales also feed in Antarctic waters (BIOMASS, 1977).

Distribution, abundance, and commercial use of Antarctic whales are listed in Table 3. Minke whales are assumed to feed for about six months in Antarctic waters, while other baleen whales are present for only about four months. About half of total sei whales and one-third of exploitable male sperm whales feed south of the Convergence

Table 1. Most important fish species of the southern ocean (after BIOMASS, 1977)

| Species | Distribution | Biology | Commercial Use |
|---|---|---|---|
| *Nothothenia rossi*<br>*(Antarctic cod)* | Coastal areas of Scotia Arc; Kerguelen, Crozet, Macquarie, Marion, Bouvet Islands | About 1 m long; spawns in April or May | estimated catch at South Georgia 400-400,000 tons per year: most heavily exploited of Antarctic fishes |
| *Champsocephalus gunnari*<br>*(an icefish)* | same as *N. Rossi* | 60-70 cm length | recent West German and Polish expeditions have found commercial quantities; caught around Kerguelen 1971-72 |
| *Micromesistius australis*<br>*(Southern blue whiting)* | Magellanic and New Zealand regions; migrates into Antarctic zone during the summer | 50 cm length; eats krill | up to 7900 tons per year in the southwest Atlantic, probably from Scotia Sea |
| *Nototheni gibberifrons*<br>*(Antarctic cod)* | Scotia Arc and Antarctic Peninsula | 50 cm length | recently taken by West Germany; possible catch by USSR |
| *Pseudochaenichtys georgianus*<br>*(an icefish)* | South Georgia, South Orkneys, Antarctic Peninsula | 50 cm length | recent West German and Polish expeditions caught significant quantities |

(Cont'd)

Table 1. (Cont'd)

| | | | |
|---|---|---|---|
| *Dissostichus mawsoni (Antarctic tooth fish)* | Circum-Antarctic, open ocean and shelf | 2 m length, 70 kg weight pelagic eggs | recently caught by West Germans near South Shetlands |
| *Dissostichus eleginoides (Patagonian tooth fish)* | Kerguelen, Crozet, Marion Islands, Magellanic-South Georgia region | smaller than *D. Mawsoni* | no catch data available |
| *Channichthys rhinoceratus* | Kerguelens *(an icefish)* | 50 cm | probably taken from Kerguelen archipelago 1971-72 |
| *Notothenia coriiceps (N. neglecta) (Antarctic cod)* | around Antarctic continent, Scotia Arc Islands, except South Georgia and Kerguelen, other Antarctic islands except Macquarie | 50 cm; spawns in May; demersal eggs | recently caught at South Sandwich by West Germans |
| *Chaenocephalus aceratus (ice fish)* | Scotia Arc islands and Antarctic Peninsula | 1-1.5 m | no catch data available |
| *Notothenia magellanica (Antarctic cod)* | Magellanic and New Zealand regions, islands near Antarctic Convergence; may migrate to Ross and Scotia seas in the summer | 40 cm; pelagic eggs; spawns in March | no catch data available |
| *Pleuragramma antarcticum (Antarctic silverfish)* | circumpolar over continental shelves; as far north as South Orkneys | 20-30 cm | has not been exploited |

Table 2. Seals in the Antarctic region (Erickson, et al., 1971; Erickson and Hofman, 1974; BIOMASS, 1977)

| Species | Distribution | Biomass | Biology |
|---|---|---|---|
| *Lobodon carcinophagus (crabeater seal)* | pack ice with small ice floes, 30-70% of water surface | most abundant in the Antarctic, probably in the world | food mainly krill; segregated by age with mature animals at pack ice periphery, younger ones toward the interior; maximum age 33 yrs; predation by killer whales and leopard seals is probably significant source of mortality |
| *Hydrurga leptonyx (leopard seal)* | pack ice | about 1-2% of crabeater seal abundance | eats krill, fish, other seals, particularly young crabeaters, and occasionally penguins; maximum age 25 years |
| *Omatophoca rossi (Ross seal)* | pack ice of 50-70% cover; very rare in Weddell Sea, higher concentrations in Amundsen, Bellingshausen and King Haakon VII seas. | rarest Antarctic seal | solitary or small groups; eats mainly cephalopods, as well as some fish and krill |
| *Leptonychotes weddelli (Weddell seal)* | near Antarctic shore stations, pupping aggregates along perennial tide cracks | about 3-6% of crabeater abundance | eat fish, crustaceans (including krill) and cephalopods |

(Cont'd)

Table 2. (Cont'd)

| | | | |
|---|---|---|---|
| *Mirounga leonina (elephant seal)* | islands for pupping | 6-10% of crabeater abundance; recovering from over-exploitation in 18th and 19th centuries | eat fish and cephalopods |
| *Arctocephalus gazella (fur seal)* | breeds on islands south of Convergence; main population on South Georgia | about half of Ross abundance; recovering from over-exploitation; may increase to original abundance in 15-20 years | eats mainly *E. Superba,* also some fish and squid |
| *Arctocephalus tropicalis (fur seal)* | islands north of Antarctic Convergence | low; recovering slowly from over-exploitation | food includes fish, squid, rock lobster |

Table 3. Whales of the Antarctic region (Mackintosh and Brown, 1974; Laws, 1977; BIOMASS, 1977)

| Species | Abundance |  | Distribution | Exploitation |
|---|---|---|---|---|
|  | # individuals $10^3$ present (initial) | total biomass $10^3$ tons present (initial) |  |  |
| *Balaenoptera physalus (fin whale)* | 84<br>(400) | 4,032<br>(20,000) | migratory; average 4 months in the Antarctic region | protected |
| *Balaenoptera musculus (blue whale)* | 10<br>(200) | 830<br>(17,600) | migratory; average 4 months in the Antarctic region | protected |
| *Balaenoptera borealis (sei whale)* | 40.5<br>(75) | 709<br>(1,387) | migratory; half the stock assumed to be south of Convergence | harvested some areas |
| *Megaptera novaeangliae (humpback whale)* | 3<br>(100) | 79<br>(2,700) | migratory | protected |
| *Balaenoptera acutorostrata (minke whale)* | 200<br>(200) | 7<br>(7) | less migratory; may average half the year in the Antarctic region | harvested |

(Cont'd)

Table 3. (Cont'd)

| | | | | |
|---|---|---|---|---|
| *Eubalaena australis (southern right whale)* | rare south of Convergence | | occasional; usually remains further north | protected |
| *Physeter catodon (sperm whale)* | 43<br>(85) | 1,200<br>(2,600) | one-third of "explitable males" in Antarctic region | harvested |
| *Orcinus orca (killer whale)* | unknown | | resident | small catch |
| *small cetaceans* | unknown, assumed small | | probably residents; biology not well known | not harvested |

(Laws, 1977). Distribution of all species is circumpolar, with larger species and larger individuals within species penetrating further south (BIOMASS, 1977).

## Benthos

Benthic communities occur along the Antarctic continental shelf and around islands. Energy sources for the benthic community come from seaweed production and from sinking of krill and other detritus from the water column.

There is no commercial harvesting of Antarctic benthos at present. Some seaweeds occur in harvestable quantities, particularly the brown algae *Macrocystis pyrifera* and *Durvillea antarctica* and red algae such as the Gelidiales or Gigartinales.

In the subantarctic, rock lobsters *(Janus sp.)* are harvested. Several antarctic invertebrates (the scallop *Adamussium colbecki*, the clam *Laternula elliptica*, the gastropod *Neobuccinum eatoni*, and sea urchins *Sterechinus sp.)* are similar to species exploited elsewhere. However, small stocks combined with logistic difficulties indicate that commercial harvesting would not be practical.

## Exchanges with Other Ecosystems

Carbon and nutrients are exported from the Antarctic ecosystem through migration of whales, some fish, and some birds. Nutrients are also lost through a presently small krill harvest, fish harvesting and whaling. A much larger krill harvest is anticipated in future years. In addition, other fish species, squid and possibly some seals constitute potential harvestable resources.

The Antarctic marine ecosystem is well integrated. Component species and relationships between them have evolved together. There do not appear to be any empty niches. All the available resources are used within the system. It is very difficult for an outside species to invade a healthy ecosystem successfully. (Only systems under stress, such as the polluted Great Lakes, are susceptible to major faunal changes). Thus, importing a new species such as salmon to migrate across the Convergence, eat krill, and then return north to be harvested, is not expected to work on ecological grounds. In the case of salmon, there are also biological and physical oceanographic problems with establishing a population north of the Convergence.

## COMPARISON WITH OTHER MARINE ECOSYSTEMS

There are several characteristics of the southern ocean which are shared with all other marine systems:

(1) Both organic and inorganic nutrients are dissolved in the water column. This nutrient reserve is analogous to nutrients held in soil in a terrestrial ecosystem.

(2) In land ecosystems, plant biomass is much greater than that of animals. This system exhibits an inverted pyramid of biomass; i.e., plant plankton standing stock at any given time is probably lower than animal plankton standing stock. However, the rapid turnover or replacement rate of the plant plankton allows the small standing crop to support the larger zooplankton biomass. As in other marine and terrestrial systems, the standing stock of other animal groups decreases with distance from plants in the food chain; i.e., standing stocks of primary carnivores are lower than standing stock of herbivores, etc.

(3) Most of the primary production in the system is carried on by single celled plants.

(4) Nutrients are recycled within the ecosystem, but energy is dissipated as it flows through the food chain.

(5) Distributions of organisms are three dimensional in marine environments. Overlapping mapped distributions of two species does not necessarily indicate that they interact, since one may be a surface and one a bottom-dwelling organism. Krill are found at the surface in the southern ocean.

(6) The biology of a marine ecosystem is closely tied to its physical environment. Light, ice cover, temperature and current movement are the most significant physical factors in the southern ocean.

(7) Productivity is higher in upwelling and coastal regions in the southern ocean as in other oceans.

There are some special characteristics of the southern ocean which are not shared by other marine ecosystems and which deserve emphasis for understanding the dynamics of the Antarctic marine ecosystem.

(1) Extreme seasonality in the light and ice regime, particularly below the Antarctic circle, dictate a very

short but intense growing season. Physiological and behavioral mechanisms have evolved to spread the production pulse and to make food available throughout the year, even when the plants are not growing.

(2) The southern ocean is productive, but not as much so as initially supposed. Early observations were made in coastal or ice edge areas during the summer. But on a per square meter per year basis, Antarctic waters are not much more productive than other oceans.

(3) However, the short food chains in the southern ocean allow a greater proportion of fixed carbon to be transferred to carnivores such as fish, birds, and mammals. Since no group is more than three steps away from phytoplankton in the food chain, the southern ocean supports an unusually dense population of carnivores.

(4) Perhaps the most significant aspect of the southern ocean ecosystem is the dependence of many predators on one prey species, krill. At first glance, ecological theory indicates that this situation should not occur; different predators tend to specialize on different prey species. However, the unusual dependence of several predators on one prey is possible in the Antarctic because each predator consumes a different segment or partition of the krill population. Predators feed in different geographic locations, inside or outside the pack ice zone, at different times of year, and take different size classes of krill.

(5) The life span of krill is very long, compared to that of other marine zooplankton. In warmer waters, zooplankton may produce several generations per year. Krill, in contrast, require several years to reach sexual maturity.

## QUANTITATIVE ECOSYSTEM DESCRIPTION

### Stock Estimates

Phytoplankton. Estimates of phytoplankton standing stock and production are derived from annual average production values for a small region extrapolated to the whole southern ocean. Production values are given in gC/m$^2$/year, but most of the primary production occurs from November through February. The average ocean area south of the Convergence is 38 x 10$^6$km$^2$ (El-Sayed, in press).

An average production value of about 16 gC/m$^2$/year (Holm-Hansen, et al., 1977) gives 6080 x 10$^6$ metric tons wet weight produced. A conversion factor of 1 gram carbon to 10 grams wet weight for phytoplankton is used (Everson, in press). A production average of 25 gC/m$^2$/year (Green, 1975) based on data for the Ross Sea produces a total production estimate of 9500 x 10$^6$ tons. An estimate of 40 gC/m$^2$/year (Currie, 1964) yields a production estimate of 15200 x 10$^6$ tons. An average production estimate of 100 gC/m$^2$/year was used by Ryther (1963). That value was a purely speculative estimate based on the concept that Antarctic waters are significantly more productive than those of other oceans. It has been shown by field data collection to be unrealistically high.

All of the values given here measure net carbon fixation rates. Losses to respiration and losses to leakage of organic matter have already been accounted for. The numbers presented here are fixed carbon which becomes available to herbivores.

Krill. In spite of the commercial and scientific interest in krill, accurate estimates of krill abundance are not available. The lack of information is partly due to sampling techniques. Normal zooplankton collecting nets do not capture krill effectively since krill are stronger swimmers than most zooplankton. High speed trawls, such as those used in the fishing of krill, are more appropriate for quantitative sampling. They have not been used over a wide enough area to provide estimates. The swarming habit of krill makes their distribution extremely patchy. It is difficult to extrapolate a catch inside of one swarm to the southern ocean as a whole.

Participants at the SCAR Conference on Living Resources of the Southern Ocean in Woods Hole, Massachusetts in 1976 discussed total krill biomass in the 200-600 x 10$^6$ tons range. On the basis of 75 x 10$^6$ tons dry weight

(Gulland, 1970) for krill, a wet weight biomass of 225 x $10^6$ tons can be calculated. Working on a production to biomass argument, with a production to biomass ratio of 1.8:1 (Allen, 1971) and a production estimate of 330 x $10^6$ tons as derived from the chart in Figure 3, a biomass estimate of 183 x $10^6$ tons is calculated. High range of krill biomass estimates is represented by 930 to 1950 x $10^6$ tons (Makarov and Shevkov, 1972).

Krill biomass estimates represent a summer or maximum standing stock. Annual average values are lower. For the remainder of the paper, discussions and calculations use the value of 250 x $10^6$ tons for an annual average and 600 x $10^6$ tons for a summer maximum biomass.

Figure 2 lists estimates of population sizes for the compartments of the Antarctic marine ecosystem as in Figure 1.

Phytoplankton production values are reliable. Extensive data collection over the whole southern ocean has contributed to the estimates. Recent estimates center around the range of 25 to 35 gC/$m^2$/year, similar to production values in other oceanic waters. However, in the Antarctic, production is concentrated in the summer season rather than spread throughout the year.

Krill estimates are not reliable. They are based on speculations, not quantitative data. However, an estimated standing stock range of 250 to 600 x $10^6$ tons and an annual production rate of 300 x $10^6$ tons are compatible with phytoplankton production estimates. A primary production estimate of 25 gC/$m^2$/year yields 9500 x $10^6$ tons available to herbivores each year. If half of that is consumed by krill with only a 10% assimilation efficiency, an annual krill production of 450 x $10^6$ tons can be supported.

Other Zooplankton

Because of the difficulties of sampling zooplankton in patches and of taking net tows in pack ice, reliable estimates of non-krill zooplankton are not available. It is usually assumed as in Gulland (1970) that the biomass of other zooplankton is the same as that of krill. This estimate is a very soft number and not reliable. However, the lack of reliability is not significant because of low utilization of non-krill zooplankton in the food chain. An indication of relative abundance of krill and other zooplankton would be useful. A specific population estimate, however, is much more important for krill than it is for other zooplankton.

| STOCK | ESTIMATED AVERAGE POPULATION SIZE | X BODY WEIGHT EATEN/YR | ANNUAL FOOD CONSUMPTION | | |
|---|---|---|---|---|---|
| | | | TOTAL | KRILL | OTHER |
| Phytoplankton Production | 6080 (16 gC/m$^2$/yr: Holm-Hansen, *et al* 1975)<br>9500 (25 gC/m$^2$/yr: Green 1975)<br>15200 (40 gC/m$^2$/yr: Currie 1964)<br>assumes area 34 x 10$^6$ km$^2$ and 1 gC : 10 g wet weight | | | | |
| Krill | 200 - 600 (Woods Hole conference)<br>225 (75 dry wt.: Gulland 1970)<br>183 (P·B 1.8:1: Allen 1971, and 330 as P estimate, chart)<br>930-1350 (Makarov and Shevkov, 1972)<br>calculations used 250 ave. and 600 max | | | | |
| Other zoopl | same as krill (Gulland 1970) | | | | |
| Fish | 14 (Green 1977, based on predation estimates) | 6.5 Everson 1970 | 91 | 64 | 27 |
| Squid | 12.4 (Green 1977, based on predation estimates) | 11 Hurley 1976 | 136 | 100 | 36 |
| Birds | 0.27 (Prevost, in press) | 67 | 18 | 14.4 | 3.6 |
| Crabeater | 3 (Laws 1977)<br>4-6 (Siniff and Hofman, pers. com.)<br>calculations use 5.5 | 23.45 Oritsland 1977 | 111 | 106 | 5 |
| Other seals | Ross 0.38 (Laws 1977)<br>fur 0.015 (Laws 1977)<br>elephant 0.3 (Laws 1977)<br>Weddell 0.25 (Hofman, p.c.)<br>leopard 0.2 (Hofman, p.c.)<br>total 0.8 | 23.45 | 18.7 | 3.1 | 15.6 |
| Baleen whales | blue 0.8 (Laws 1977) | 4.2 (Lockyer 1976) | 3.5 | 3.4 | 0.1 |
| | fin 4 " | | 16.9 | 16.4 | 0.5 |
| | humpback 0.08 " | | 0.3 | 0.3 | 0 |
| | sei 0.7 " | | 3.0 | 2.9 | 0.1 |
| | minke 1.4 " | 14.6 | 20.4 | 19.8 | 0.6 |
| Toothed whales | sperm 1.16 (Laws 1977) | 4.2 | 4.9 | 0 | 4.9 |
| | killer 0.05 (rough guess) | 25 | 1.25 | 0 | 1.25 |

Fig. 2. Stock and krill consumption estimates, Units 10$^6$ metric tons wet weight.

Fish. The fish abundance estimate in Figure 2 is an indirect calculation. The amount of fish consumed by fish predators, as in Figure 3, is 14 x $10^6$ tons per year. Derivation of this value will be discussed later. Assuming conservatively that annual production is equal to standing stock for fish, biomass is 14 x $10^6$ tons. If annual production is less than the average standing stock, then the biomass estimate should be revised upward.

From a study on fish in the South Orkney Islands (Everson, 1970), an annual consumption rate of 6.5 times body weight is derived. A fish stock of 14 million tons then consumes 91 x $10^6$ tons of food per year, about two-thirds krill and the remainder other organisms. Values for fish standing stock and krill consumption are educated guesses, and are most likely to be underestimates.

Squid. The biomass estimate in Figure 2 is based on predation on squid, another indirect estimate. Previous estimates of Antarctic squid biomass have been based on the population size required to support predation by sperm whales, a major squid predator. However, from Figure 3, seals, birds, and possibly fish together consume at least twice as much squid as do sperm whales. Therefore, squid population estimates have been revised upward (Green, 1977). Estimated yearly predation on squid in the southern ocean amounts to about 19 x $10^6$ tons. On the assumption that squid populations turn over faster than fish do and that annual production is one and a half times standing stock, a squid standing stock of 12.4 x $10^6$ tons was derived. This estimate is speculative and not reliable. It is higher than previous estimates, but may still be conservative.

An annual consumption rate of eleven times average body weight is extrapolated from laboratory studies (Van Heukelem, 1973; Hurley, 1976). The total consumption by a stock of 12.4 x $10^6$ tons of squid would be 136 x $10^6$ tons of food per year. Squid may consume 100 x $10^6$ tons of krill annually (D. Tranter, Woods Hole Conference).

Fish and squid estimates are the least reliable numbers in Figure 2 since they are not based on any direct data. One concern expressed at the Woods Hole Conference was the need for improved data on fish and cephalopod stocks. This information is essential, because fish and squid feed extensively on krill and they are potentially harvestable resources.

Birds. From an extensive review of population and physiological data available for Antarctic birds (Prevost, in press), a standing stock of 0.27 x $10^6$ tons for waters south of the Convergence was estimated. The bulk of this biomass is Adelie penguins which subsist primarily on krill. Antarctic birds consume 67 times their body weight per year, for a total prey consumption estimate of 18 x $10^6$ tons. Proportions of krill and other species in bird diets were given for the Antarctic and subantarctic regions combined. Correcting these ratios to allow for the dominance of Adelie penguins south of the Convergence, birds consume 14.4 x $10^6$ tons of krill annually.

Because birds are easy to census, since they breed in colonies and in accessible land areas, the bird biomass and consumption data are very reliable.

Birds have a relatively large impact on the ecosystem in proportion to their standing stock because of their high consumption rates. However, compared to seals and other species as krill consumers, birds have a relatively small impact. However, penguins may prove to be useful indicators of krill abundance (Green, 1975). Data on penguin population size and breeding success can provide an important key to the condition of krill standing stocks. Birds are much easier to sample than are zooplankton.

Crabeater seals. Crabeater seals are by far the most abundant of Antarctic seals. Population estimates vary from 15 million individuals (Laws, 1977) to between 20 and 30 million individuals (Hofman, conversations at Woods Hole Conference) to estimates of 30-70 million individuals (Erickson, et al., 1971). For the rest of the paper, calculations use 25 million individuals or 5.5 x $10^6$ tons of crabeater seals.

Using an annual consumption rate of 23.45 times average body weight (Oritsland, 1977), total consumption by crabeater seals is 111 x $10^6$ tons of food. Since their diet is 94% krill (Laws, 1977), they eat 106 x $10^6$ tons of krill annually.

Biomass estimates for other seals are from Laws (1977) and Hofman (discussions at Woods Hole Conference). Total biomass estimated for other seals is 0.8 x $10^6$ tons (compared to a total of 5.5 x $10^6$ tons for crabeater seals alone). Other seals consume a total of 18.7 x $10^6$ tons per year of which 3.1 x $10^6$ are krill (after Laws, 1977).

Whales. Baleen whales found south of the Convergence are blue fin, humpback, sei, and minke whales. Fin whales are the most abundant with a total estimated biomass of 4 x $10^6$ tons. Minke whales, although less abundant, consume more because they feed for a longer period of time in the

Antarctic than fin whales. Present annual consumption of krill by whales is approximately 42 x $10^6$ million tons (Laws, 1977), less than half of the total consumption by seals and also less than consumption by squid.

Sperm and killer whales are present in the Antarctic ecosystem, but do not consume krill directly. They eat fish and squid and are one step removed from krill in the food chain.

Data on whales are based on fishery statistics and are very good estimates of population size and consumption rates. Seal information is almost reliable as that of whales. Both aerial and shipboard techniques have been used to estimate seal populations.

In Figure 2, phytoplankton production and bird, seal and whale standing stocks are the most reliable numbers. Krill and other zooplankton estimates are considerably less reliable. Fish and squid estimates are the softest numbers in the table, essentially educated guesses.

## Predation Table

Figure 3 shows estimates of the total biomass flowing along the arrows of the conceptual model of Figure 1. Values are in units of $10^6$ tons and represent annual totals for the area south of the Convergence. Flows are located with the donor compartment as column heading and the receiver compartment as row heading. Flow from krill to penguins, which represents consumption of krill by penguins, is in the krill column and penguin row of the matrix and is 14.4 x $10^6$ tons per year.

Ice algae production is about 5% of phytoplankton production (Green, 1977). Ice invertebrates feeding on ice algae provide a mechanism for putting that carbon into the water column. Zooplankton and fish larvae eat ice algae. For the higher trophic levels, the matrix has been derived from the predator perspective.

Estimates of predation on krill by fish, squid, penguins, seals, and baleen whales were documented in the discussion of Figure 2. Consumption of other zooplankton, fish, squid, and birds are from Green (1977), Laws (1977) and Prevost (in press).

Bird and mammal consumption rates are based on extensive data. Fish and squid consumption rates are speculative.

TO FROM

| | Ice Algae | Ice Invert. | Phyto-plankton | Krill | Other Zoopl. | Fish | Squid | Birds |
|---|---|---|---|---|---|---|---|---|
| Ice Algae | | | | | | | | |
| Ice Inverts. | 90 | | | | | | | |
| Phyto-plankton | | | | | | | | |
| Krill | 75 | | 2500 | | | | | |
| Other Zoopl. | 75 | 4 | 2000 | | | | | |
| Fish | | 10 | | 64 | 11 | | 6 | |
| Squid | | | | 100 | 34 | 2 | | |
| Penguins | | | | 14.4 | | 1.8 | 1.8 | |
| Crabeater Seals | | | | 106 | | 3 | 2 | |
| Other Seals | | | | 3.1 | 1 | 7 | 4.7 | 0.5 |
| Baleen Whales | | | | 42.8 | | | | |
| Toothed Whales | | | | | | 0.5 | 4.6 | 0.3 |

Figure 3. Annual total consumption. Units $10^6$ metric tons net weight.

Figure 3 represents the best present estimates of consumption within the Antarctic ecosystem. The matrix indicates that squid and crabeater seals are the most important consumers of krill. Baleen whales consume only about a fifth of the total taken by squid and crabeaters.

## SUMMARY ECOSYSTEM DESCRIPTION

The term krill refers to several species of zooplankton in the Antarctic ecosystem. The dominant species, and the only one of commercial interest, is *Euphausia superba*. Krill is sometimes used as a synonym for this species. *E. superba* is rarely found north of the Antarctic Convergence, but is abundant immediately south. Some fish, bird, and seal species exhibit the same distribution pattern, circumpolar south of the Convergence. All waters south of the Antarctic Convergence belong in the Antarctic ecosystem. The Antarctic marine food web is centered around krill.

The Antarctic ecosystem is unusual ecologically since one species, krill, provides the major food resource for fish, squid, birds, crabeater seals, and five baleen whales. The timing of whale migrations, the fluctuation of the pack ice, and the relationship of seal distribution to pack ice type provide for some partitioning of the krill resource. The partition taken by fish and cephalopods is not known, although both groups are thought to be significant predators on krill.

Krill play a key role in the nutrient dynamics of the Antarctic marine ecosystem along with other zooplankton and phytoplankton. They facilitate nutrient regeneration in the euphotic zone during the growing season. Harvesting of krill, fish, and whales removes nutrients from the Antarctic ecosystem. Nutrients are brought into the system by extensive upwelling.

The biology of the Antarctic ecosystem is closely regulated by the extreme seasonal variations in availability of light and in areas of sea ice. The circumpolar current unifies the system through transport of nutrients and plankton.

Krill have a circumpolar distribution as do most birds and mammals. The distribution of fish and squid species is less well known. Whales and at least one fish species migrate across the Convergence. Squid are probably most abundant near the Convergence, and may cross it.

## KRILL PRODUCTION

Total predation on krill by fish, squid, birds and mammals amounts to approximately 330 x $10^6$ tons per year. This value is an estimate of production by the krill population.

The ratio of annual production to average biomass is an estimate of turnover rate for the krill population. Production estimated by predation is roughly equal to the average standing stock and about half of the peak annual biomass. Turnover of 50 to 100% of the population in a year is slow for marine zooplankton. However, Antarctic krill are long-lived in comparison with other zooplankton, so this figure is not so surprising.

The questions of krill life span and age of sexual maturity are not yet resolved. Data on size distribution can be interpreted in several ways (Fraser, 1937; Bargmann, 1945; Ivanov, 1970). Krill do not breed until the beginning of their third or fourth year, lengths of 28 to 45 mm, and may breed one or two seasons (McWhinnie, letter to K. Green, 18 October 1977).

Life span questions affect estimates of krill replacement rates and consequently estimates of sustainable yield. With present uncertainty on development rates, the proportion of the population that is capable of reproducing in any year cannot be determined.

## KRILL HARVEST QUESTIONS

### Surplus Argument

Mention of krill as a harvestable resource is invariably connected with an observation on the decline of whales in this century. The argument is essentially that an amount of krill equivalent to the difference between present consumption and peak consumption by whales can be harvested. Assumptions associated with this argument are that man can exactly replace whales as a predator in the Antarctic ecosystem and that consequently harvesting will have no impact on the rest of the system. This argument is no longer considered valid by scientists, but remains a part of the public attitude on Antarctic resource potential.

There are several very strong arguments against the assumption that krill harvesting will not affect the Antarctic marine ecosystem. First, harvesting can not exactly replace whales as a predator. The fraction of the krill population which the whales consumed, with a specific circumpolar distribution, time of year, size of krill removed, and relationship to pack ice, will not be duplicated by commercial harvesting.

Second, there is evidence that the ecosystem has already adjusted partially to the reduced whale population. Penguins and some seal populations appear to have increased to take advantage of more available krill (Conroy, 1975; Laws, 1977b).

A large commercial krill harvest will compete with krill predators. With the change in abundance of krill available to the ecosystem, there will be changes in predator populations. It is suggested that populations will return to 1900 levels -- i.e., to what they were when whale populations were considerably higher (J. A. Gulland letter to K. Green, September 1977). Population levels for fish, cephalopods, birds and seals around 1900 are not known, however.

### Yield Estimates

The estimate of total predation on krill from Figure 3 is approximately 330 x $10^6$ tons. Any commercial harvest will be taken from those 330 x $10^6$ tons. Harvesting will displace some predators.

Literature estimates of sustainable krill harvest range from 70 to 150 x $10^6$ tons per year (Moiseev, 1970;

Mackintosh, 1970; Everson, in press). Public expectations are even higher (e.g., 200 x $10^6$ tons, Gwynne, 1977).

Changing the perspective from only krill and whales to the whole ecosystem, estimated harvesting levels appear to be too large. A harvest of 150 x $10^6$ tons would displace half of the current predators, producing dramatic changes in the ecosystem.

The estimate of 330 x $10^6$ tons for krill production is a sum over the whole southern ocean area. A local harvest, say 10 x $10^6$ tons in the Scotia Sea, would probably cause observable changes in predator populations there. My present educated guess for a sustainable yield, based on possible replacement rates and ecosystem interactions, is 30 to 60 x $10^6$ tons per year for the southern ocean, with the larger value less likely to be sustainable over a long time.

To try to maintain balance within the food web, predators could be harvested in proportion to prey (krill) harvested. Sustainable harvests of seals, birds, fish and cephalopods cannot be estimated well at present because of lack of information on replacement rates within each of those stocks. As a rule of thumb for general consideration only, a total predator biomass of about 10% of the total krill harvest could be taken. Thus, 30 x $10^6$ tons of krill harvested would imply a total of 3 x $10^6$ tons for seals, birds, fish and cephalopods. About half of that total would be crabeater seals. A concomitant harvest would necessitate management of all the resources, including krill, by one agency. To meet the objective of maintaining a balanced ecosystem, the geographic locations of all the harvests would have to be coordinated as closely as the total removed. Predators should be removed from essentially the same location as prey. Population dynamics within each species must also be taken into account.

## MANAGEMENT AND CONSERVATION CONCERNS

Management concerns from an Antarctic ecosystem perspective in the area of environmental sensitivity to a krill harvest are:

(1) recovery rates of baleen whale populations. Baleen whales are not a significant predator on krill at present. Even when whale populations were greatest, baleen whales probably consumed only about half of the krill available to predators (Green, 1975). Recovery rates of baleen whale populations depend on the age at which whales reach sexual maturity as well as on total population numbers. Whales now become sexually mature sooner than they did at the turn of the century (Gambell, 1976). This promotes a rapid recovery of the population and may be due to good physiological condition from abundant food supply. A reduction in krill might cause a rise in the age of first reproduction and, consequently, slower recovery of the baleen whale populations. In addition, a harvest will be competition for food, limiting the potential sustainable baleen whale population size.

(2) abundance of potentially harvestable fish and squid. Fish and squid are potentially harvestable resources. They are probably easier to market than are krill even though they may be more difficult to catch. Some commercial fishing is already occurring in Antarctic waters. A substantial krill harvest could interfere with existing and potential fisheries by reducing prey availability and consequently overall population size.

(3) populations of penguins and seals. A large krill harvest acting as a competitor for penguins and seals could easily result in a reduction in penguin and seal populations. The most affected would be crabeater seals, a potentially harvestable resource.

(4) trophic structure of the Antarctic marine ecosystem. The harvest of krill is not analogous to the harvest of whales. A whale is a top carnivore or an end of a food chain. Some baleen whale populations were reduced to less than a fifth of their highest levels. While there have been adjustments within the Antarctic ecosystem to changes in whale populations, the basic structure of the system remains the same. If krill populations were reduced comparably, the entire character of the Antarctic ecosystem would be changed.

Some additional information is necessary for the conservation and management of krill stocks. Breeding stocks must be identified. Data is needed on the abundance, distribution, age structure, and reproductive physiology of krill.

Limited commercial harvesting can provide some of the data necessary for calculating sustainable yields. In the event of any krill harvest, data should be collected, reported and analyzed: location, time, search time to locate a swarm, gear used, swarm size, shape and depth, size composition of the catch, and breeding condition.

Monitoring the rest of the system for a response to the krill harvest is also essential. Nutrient levels and primary production rates in the vicinity of krill harvesting should be measured. If possible, fish and cephalopod populations should be evaluated. Birds, particularly penguin populations, should be monitored closely as potential indicators of changes in krill abundance. Seal and whale data are already being collected under existing conventions.

A controlled krill harvest can be treated as an experimental manipulation of the Antarctic marine ecosystem. With careful observations, data pertinent to the ecology of the system as well as to management of the fishery can be obtained.

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# APPENDIX F

## The Living Resources of the Southern Ocean:
## Krill

Southern Ocean Fisheries Survey Programme GLO/SO/77/1

# THE LIVING RESOURCES OF THE SOUTHERN OCEAN

by

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

UNITED NATIONS DEVELOPMENT PROGRAMME

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## THE SOUTHERN OCEAN FISHERIES SURVEY PROGRAMME

In view of the potential importance of the living resources of the Southern Ocean, the United Nations Development Programme (UNDP) Governing Council approved in January 1976 a preparatory phase of a Southern Ocean Fisheries Survey Programme, to be executed by the Food and Agriculture Organization of the United Nations (FAO). The long-term objective of the Programme is to improve the knowledge of the nature, magnitude and distribution of the living resources of the Southern Ocean (South of latitude 45°S), with a view to assisting in their eventual rational utilization. The immediate activities of the preparatory phase (to continue until the end of 1977) include a review of the present information on the distribution and magnitude of the living resources of the Southern Ocean; a review and evaluation of the present state of exploitation and utilization of these resources; and the establishment of a system for regular compilation of statistical and other information about them.

This report is one of a series prepared by FAO under the preparatory phase of the Programme. It gathers together current knowledge on the magnitude and distribution of the living resources of the Southern Ocean. Other reports in this series assemble current knowledge on the technology of harvesting and on the utilization of krill.

E.S. Holliman
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M-43

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# 6. KRILL

## 6.1 Introduction and General Biology

There are in the Southern Ocean several commonly occurring species of euphausiid crustacean. These are listed below and their approximate latitudinal ranges shown in Fig. 6.1.

*Euphausia superba*
*Euphausia vallentini*
*Euphausia triacantha*
*Euphausia frigida*
*Euphausia crystallarophias*
*Thysanoëssa macrura*

The distribution of these species along with an identification key are described by Mauchline and Fisher (1969) and more detailed information is available in John (1937) and Baker (1965) (*Euphausia* species), in Baker (1959) and Marr (1962) (*Euphausia triacantha*), Marr (1962) (*Euphausia superba*) and in Nemoto and Nasu (1958) (*Thysanoëssa*).

Of these species *E. superba* (Fig. 6.2) is the largest and most abundant and is the species generally considered as being synonymous with the term "Antarctic Krill". It is this species which is of greatest interest from the fisheries point of view since its habit of congregating into dense swarms makes it an ideal target for modern midwater trawlers. The bulk of this section is therefore in the main restricted to information on *E. superba* although other species have been occasionally found to be more abundant in some areas of the Southern Ocean (Nemoto, Doi and Nasu, in press, found *E. vallentini* and *Thysanoëssa macrura* predominated in six out of 318 samples).

Before reviewing in detail the information on *E. superba*, a brief outline of some of the essential features of its general biology will be given in order to assist the reader in gaining a clear understanding of the processes which are described in the sections which follow.

The main part of the spawning season for *E. superba* occurs from January to March. The eggs, about 0.7 mm in diameter, are released at the surface and then sink to considerable depth, almost certainly to the lowest levels of the warm deep water. During the weeks which follow the eggs hatch into nauplii and, whilst rising through the water column, develop through a metanaupliar stage to arrive at the surface as first calyptopes. They then develop through two further calyptopis and six furcilia stages before being classed as adolescents. During the subsequent two or more years the krill increase in size to a maximum length of about 6 cm. and are to be found, for the most part, in the top 200 m of the water column. Any diurnal vertical migration that does occur is thought to be within the Antarctic surface water so that in the West Wind Drift the krill are in water masses having a slight northerly component.

The more or less total restriction of *E. superba* to the surface water may well be associated with the fact that it is the only species of euphausiid which at least during the summer feeds predominantly on phytoplankton. Other food types are however taken depending upon availability.

The habit of *E. superba* of congregating in dense swarms has been well known for a long time. The swarms themselves are often several hundred metres across and within them the krill may be as concentrated as several kilograms in a cubic metre of water. Thus, within a region of above average abundance the distribution is extremely patchy.

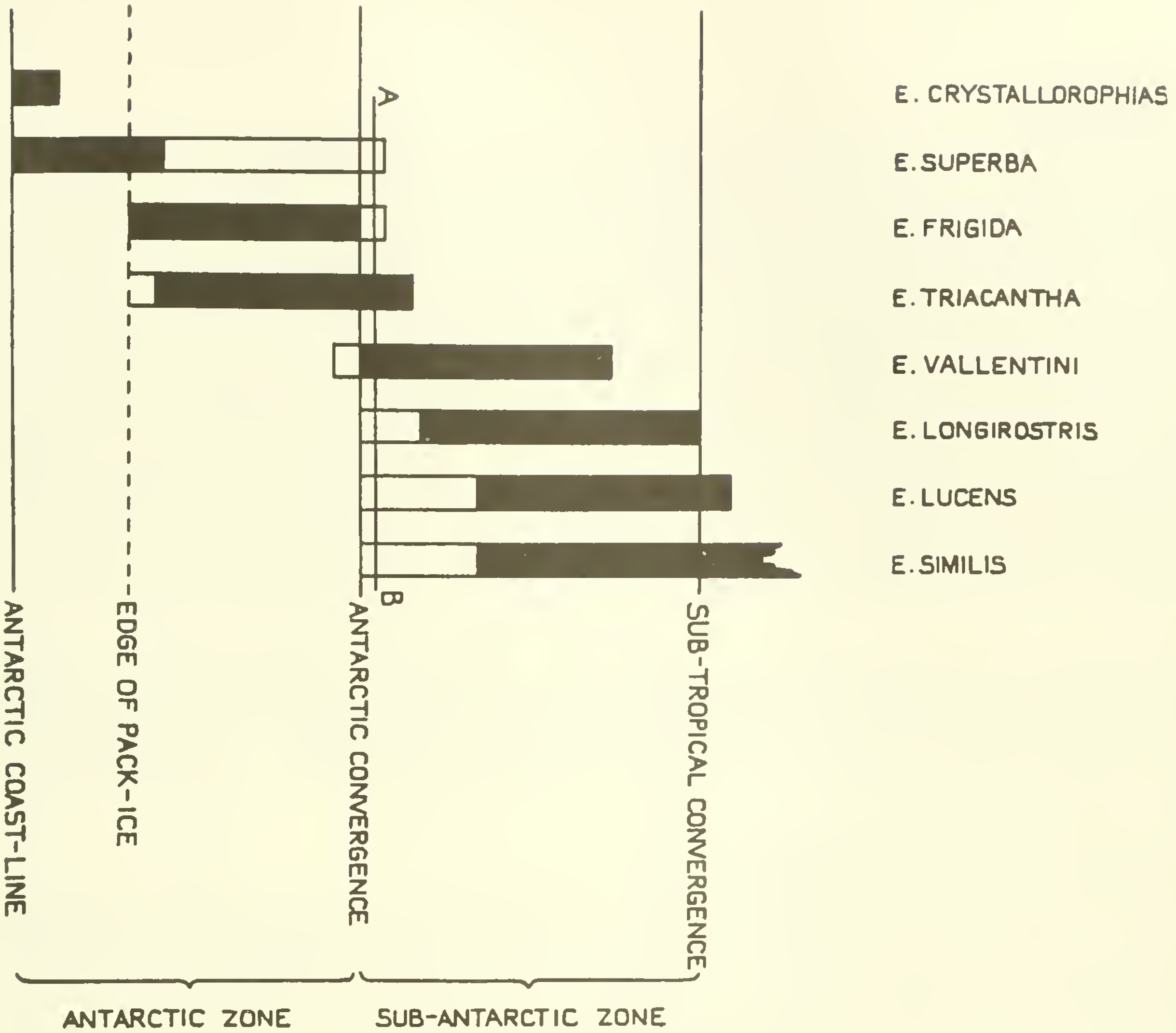

Fig. 6.1 Distribution of species of Euphausia in the surface waters of the Antarctic and sub-Antarctic zones (John 1937). The blacked-in portion of each column shows the normal range of that species, the entire column the possible range.

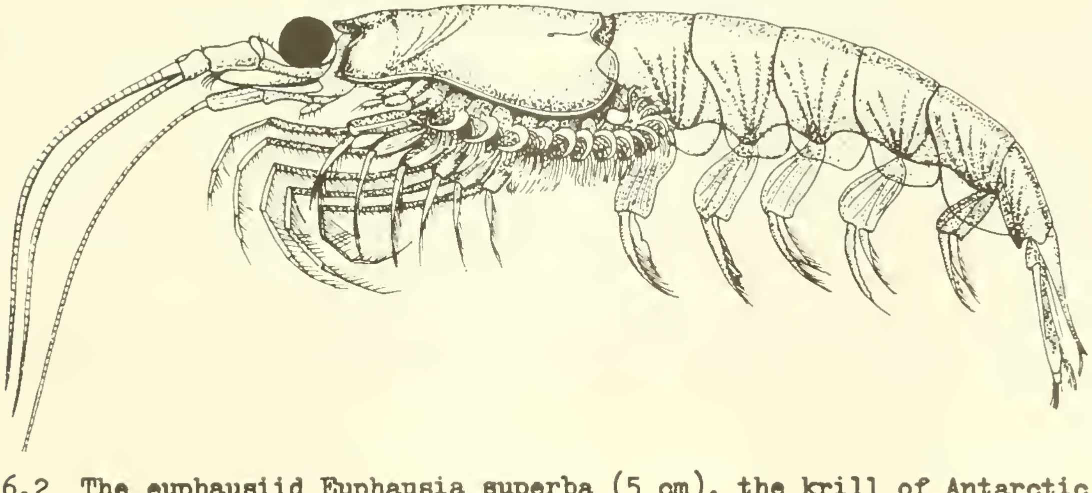

Fig. 6.2 The euphausiid Euphausia superba (5 cm), the krill of Antarctic waters (Clarke and Herring 1971)

## 6.2 Distribution

In broad terms the overall geographical distribution of E. superba may be taken as being circumpolar south of the Antarctic convergence (Marr 1962, Baker 1954) and is one of the dominant macroplankton organisms. (The dominant components of the macroplankton in the Pacific sector may be Salps and Coelenterates (Barkhatov et al. 1973) although Mackintosh (1973) thinks most of the krill there are in the East Wind Drift and therefore in the Pack Ice Zone). There are few records of E. superba occurring north of the convergence. Mackintosh (1973) described krill north of South Georgia in a tongue of cold water, Sasaki et al. (1968) described a concentration at 45°S 145°E and Dall and Dunstan (1957) found fresh krill in the stomach of a humpback whale caught off Queensland. Marr (1957) considers such occurrances of minor importance. Within these very broad limits the density of krill is extremely variable. Marr (1962) describes the major concentrations as occurring in the East Wind Drift, Scotia Sea, Weddell Drift and South Georgia areas although Mackintosh (1973) has shown the existence of large concentrations elsewhere. As a result of recent sampling Nemoto (1968) has shown the presence of large concentrations in the vicinity of the Kerguelen Gaussberg Ridge and at Longitude 150°W (see also map in Mackintosh 1973). This area of concentration is also suggested by Beklemishev (1960, 1961) on the basis of whale catches in the region.

Because krill concentrations tend to occur in certain clearly defined areas, it has been suggested that these may represent several self maintaining populations (implied by Mackintosh 1973) or even distinct races (Makarov 1974). Clearly whether or not such a system is present will have direct effect on the way in which this resource is managed. In this review, the distribution of all life stages has been considered in order to lead to an overall understanding of the population structure.

### Distribution of eggs and early larvae

In an analysis of the vast collection of material collected by Discovery Investigations, Marr (1962) showed that E. superba spawns in the surface layers (although Fraser (1936) considered that spawning occurred on the bottom in the shelf zone). The eggs then sink and begin the processes of cleavage leading to hatching. The scarcity of cleaved eggs in the surface samples and the fact that Bargmann (1937) records spawning in aquaria but without subsequent cleavage implies that depth (probably pressure) may be necessary for development. Hatching is thought to occur in deep water and the resultant nauplii moult through the metanaupliar stage as they rise through the water column to reach the surface as first calyptopes. This description of the cycle of events is clear from Marr's (1962) analysis. What is not clear and which has been the subject of a great deal of study are the details of locality, time and conditions under which these events take place.

Although Marr (1962) recorded both gravid and spent females in the oceanic surface water, he considered that hatching in the oceanic deep water far away from the shelf was negligible. He did however consider that the early larvae were carried in the cold bottom water away from the continental shelf to undergo the developmental ascent in the oceanic deep water. This is shown diagrammatically in Fig. 6.3.

In his analysis Marr considers very carefully all the evidence both for and against this explanation because it clearly has a great deal of bearing on the dynamics of distribution. In this respect the important factors are the time taken over the early development and the rates of flow of the cold bottom water and warm deep water.

There is at present no direct information on early development rates for E. superba. Marr assumed that E. superba would take about half as long again as the 15 days Meganyctiphanes norvegica takes to reach the first calyptopis stage (p. 207). Mackintosh (1972) also considers three weeks to be a reasonable estimate although his analysis is based on much the same information as Marr's.

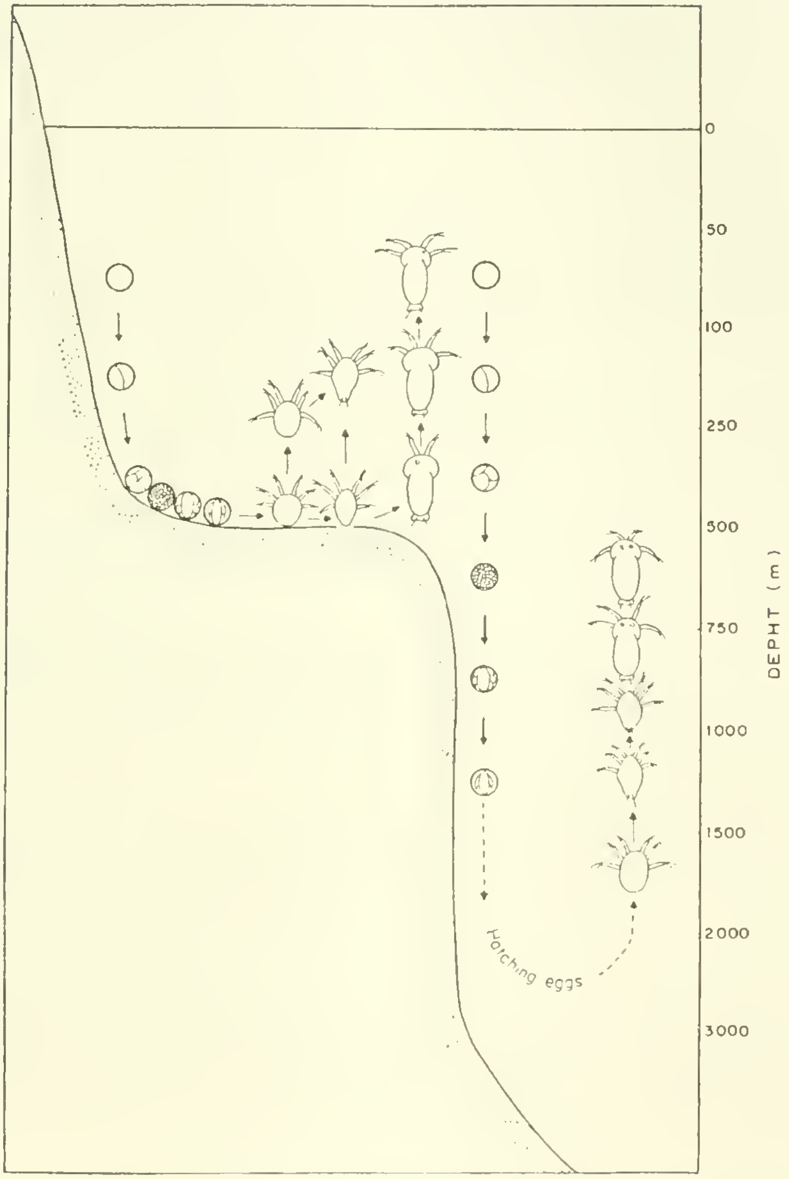

Fig.6.3 Vertical distribution and migration of the early development stages of krill on the shelf (left), and in deep water (right), (redrawn from Marr (1962)). Hatching in shallow water can give rise to the occurrence of nauplii and metamorphis unusually close to the surface

Little evidence is available on the rate of flow of the various deep water masses although Marr (p. 212) does give evidence that in places the Antarctic Bottom Water could flow north with considerable force.

In a recent re-examination of the distribution of eggs and larvae,Voronina (1974) states that spawning occurs in oceanic waters (cites Dolzhenkov 1973 and Makarov 1973) and also at South Georgia, a marginal area of its distribution range (cites Mackintosh 1973 and Makarov 1972)1/ and suggests that spawning probably occurs over most of the range of the species. Voronina suggests that the Antarctic Bottom Water rather than carrying the eggs and larvae does in fact form the physical lower limit for the sinking eggs. Successful development is assumed to be a direct function of depth and a maximum depth of 1 800 m is suggested as being the greatest vertical distance through which the larvae can migrate using the limited food resources in their yolk sacs.

The 1 800 m boundary layer does encompass most of the localities in which early larvae have been found although Voronina does mention that some of the stations from which they were taken in the Scotia Sea fall outside this limit. Another criticism is that in many cases the larvae will not arrive in the surface water until late in the season after the peak of primary production. Adolescent and adult E. superba have been shown to be capable of feeding on detritus (Pavlov 1974) and there would seem no reason why the larvae should not do the same. In that case there is only an advantage in being at the surface during the primary production season. Thus although the 1 800 m boundary layer may for the most part describe the northern limit of successful spawning this is probably a coincidence.

In his analysis of the life cycle of E. superba, Mackintosh (1972) to a great extent avoids the direct issue of oceanic versus shelf area spawning and concentrates on the distribution of the subsequent developmental stages. However, the implication of his conclusions is that he, like Voronina, considers that spawning occurs over much of the ocean as well as the shelf area. He makes a strong case for the early larvae being distributed in areas where low sea temperatures extend to great depth (see also Marr, Fig. 81). The major areas he identifies as holding early larvae are the East Wind Drift, Bransfield Strait and the divergence zones he describes in the Scotia Sea and Weddell Drift.

## Vertical distribution of later stages

In a long and detailed analysis of the "Discovery" samples, Marr (1962) suggests that the major concentrations of E. superba occur in the top 100 m and within this stratum most frequently in the top 10 m. In his analysis Marr is careful to minimise error due to avoidance, a major problem with the 1 m.diameter and smaller nets from which his samples were obtained. Although massed in the surface waters for most of the day and night Marr does suggest that there is a pattern of diurnal migration but was unable to specify the conditions under which it occurred. The supporting evidence that Marr cites, based on the depths at which whales and birds feed, is not particularly helpful in this context as it only confirms that krill occur near the surface at some time during the day or night (a fact known from the net hauls). What is perhaps more important is that there is a clear indication (Marr 1962, Table 35) that adolescent and post larval krill are not present in significant numbers in the Warm Deep Water.

Recent Russian research using echosounders has shown a tendency for sexually mature krill to undergo diurnal vertical migration in the top 80 m of the water column (Shevtsov and Makarov 1969), and Pavlov (1969, 1974) has obtained results indicating that this vertical migration

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1/ Makarov (1972) refers to spawning in the frontal zone between Weddell and Bellingshausen water which would be oceanic. Mackintosh (1972) does not describe spawning as occurring near South Georgia but considers it possible although Marr (1962) considers that no successful spawning occurs in the region.

is directly associated with feeding (although no indication is given of how widely applicable these observations are). When the krill are feeding actively they rise to the surface and are dispersed. They come together as swarms when they are replete, stop feeding and then descend. Pavlov suggests that the onset of swarm formation and the duration of the swarm is directly related to food availability. Nakamura (1974) described a similar type of vertical migration although he does not link this to feeding pattern directly. Assuming that availability of food is a major factor in controlling swarm formation it would be expected that swarms would occur more frequently during the summer when primary production is at its maximum than during the winter.

Feeding studies by Pavlov (1971, 1974) have shown that detritus plays an important part in the diet of E. superba which would allow them to feed all year round in deeper water. Although Pavlov (1969) describes the guts of krill caught at 300 m as being empty and therefore not feeding, the fact that their main lipid store is not in the form of waxes (Bottino 1974) suggests they do not go without food for long periods (see Sargeant and Lee 1975). Also Mauchline and Fischer (1969) suggest by comparison with other euphausiids that E. superba although feeding on phytoplankton by preference will also feed on detritus and animal material.

In addition to this information regarding migration in the surface water Shevtsov and Makarov (1969) also describe significant concentrations at over 200 m depth although it is not clear whether these were detected by echosounders or solely by fishing at predetermined depths. Confirmation of this observation may be inferred from Permitin's (1970) observation that krill forms an important component in the diet of several demersal fish species in the shelf area (see also section on Fish in this paper). More recently significant deep water concentrations of krill have been identified in shelf areas of the Scotia Arc where there was no marked temperature discontinuity (Fischer 1976).

The fact that these recent observations conflict with those of Marr can be attributed to either a changing behaviour pattern by the krill or else due to the different techniques involved in estimation. Marr, in considering reasons for the disparity in the daytime and night time catches finds some evidence that the difference is not due to a diurnal vertical migration beyond the normal range of the nets, but that it is more likely to be due to avoidance or the fact that subsurface swarms represent a poor target for obliquely hauled nets. The difference may also be due to the methods employed. There is clearly a need for standardised sampling in conjunction with acoustic detection devices in order to quantify the krill concentrations in both the surface water and also in the intermediate water.

### Horizontal distribution of later stages

From the time that they arrive in the surface waters until they spawn two years or more later, a significant proportion of the krill must move, or be carried, to an area from which spawning will result in maintenance of the stock. Over most of the Southern Ocean the surface water has a mainly easterly and to a lesser extent northerly set. The result of this is that krill which occur in that area will be naturally carried away northwards.

Within the general area of the East Wind and Weddell Drifts, which contain the major concentration, the distribution is very patchy. In addition to this the habit of E. superba in forming swarms has made detailed distributional study liable to considerable error. Recent fishing expeditions have, however, identified concentrations regularly in clearly defined areas. These are in the area of mixing of the circumpolar and Weddell currents (Gershanovich and Lyubimova 1971) particularly to the north of the South Orkneys (Burukovskii and Yaragov 1967), on the lee side (in terms of dominant wind and current) of islands and submarine ridges and also in areas of descending currents bordered by ascending currents (Elizarov 1971) and off South Georgia (e.g., Elizarov 1971, Makarov, Naumov and Shevtsov 1970, Bogdanov and Solyanik 1970). In the East Wind Drift zone concentrations have been found around 100°E (Nasu 1974) and from 130°E to 170°W (Ozawa et al. 1968). All of these observations were made during the summer months and also in areas of swarms. The only major concentrations that occur outside the East Wind and Weddell Drift zones are reported from the north of the Ross

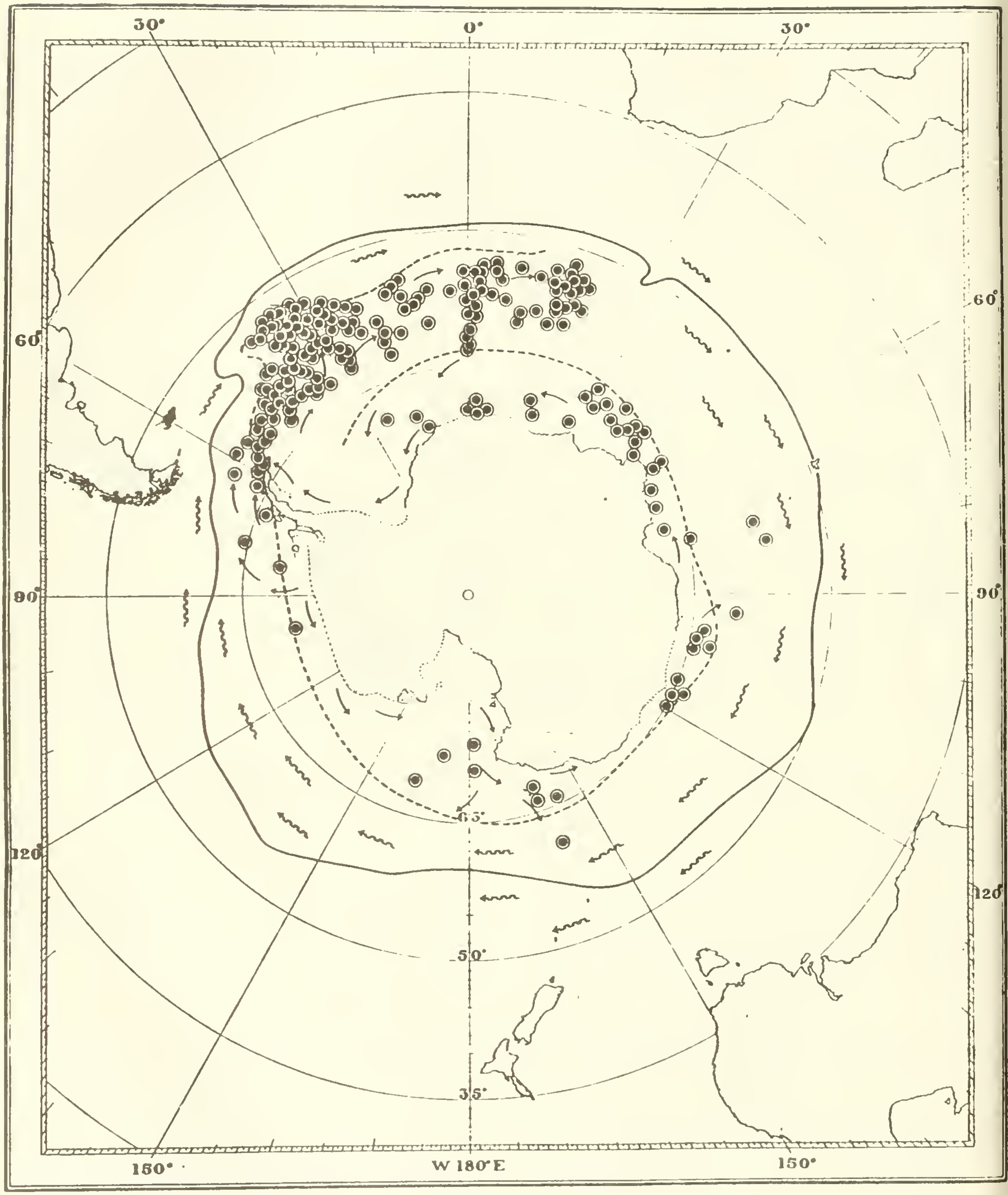

Fig. 6.4 Principal concentrations of the Antarctic krill (Marr 1962).

Sea (Hodgson 1902, Marr 1962) and the Kerguelen Gaussberg Ridge area (Nemoto 1968) a region poorly sampled by Discovery Investigations (16 stations total from November to April).

The catches by commercial type operations indicate a distribution very similar to that described by Marr (1962) on the basis of plankton net samples (his Fig. 5 and 6). (see Figure 6.4).The limited number of large catches in the West Wind Drift zone can be attributed to one of two factors. Either krill in this zone do not tend to swarm and although present in large quantities do not occur in dense concentrations or their total quantity in the region is lower. Mackintosh (1973) suggests that krill concentrations in Indian Ocean sector of the West Wind Drift are progressively grazed down by the whales as they migrate south. It is not however clear whether the whale migration south is maintained because of food requirements.

Theories of distribution control

There are in the literature a wide variety of theories which attempt to explain the reasons for the occurrence of the various life stages around the Antarctic continent. None of these theories is totally proven. The more plausible will therefore be considered along with the major evidence that is available in support and against.

Perhaps the simplest explanation is that throughout their life history krill remain more or less in the same location (Marr 1962). Mackintosh (1972) quotes an average surface flow rate in the West Wind and Weddell Drifts of 18 cm/sec. which is within the range of swimming speeds determined by Semenov (1969) for adolescent and adult krill. Although it is not known for how long krill could maintain this speed Marr (1962, p. 155) quotes from some notes made by E. R. Gunther who observed a swarm of krill swimming against an estimated ⅓ knot current for several hours. It is also possible for krill to be maintained in more or less the same locality by migrating between the warm deep water and surface water (they are known to occur in significant numbers down to 400 m (Shevtsov and Makarov 1969)) although Fischer (1976) has suggested that such a temperature discontinuity may represent a physical barrier. The eddying effect around islands and submarine rises could also, as suggested by Makarov (1972) and Khvatskiy (1972) hold krill in an area for a prolonged period.

The remaining theories require that the krill are carried in a wide circulation pattern and the most frequently considered area from this point of view has been the Weddell Sea. Ruud (1932) basing his ideas on the circulation pattern of Meyer (1923) suggests that some larvae and adults get carried back to the high latitudes in the surface stream. Marr (1962) whilst agreeing that there is an undoubted circulation pattern of this type believes that the circulation involves an area far further east and that in addition in order to complete the cycle the larvae would need to be carried south in the intermediate water during the developmental ascent. The easterly spreading of early larvae in the surface waters is clearly shown in Marr's distribution maps (Fig.64 onwards) which gives considerable weight to the greater part of this circulation theory.

Makarov (1972) using recent information from the Scotia Sea has taken the theory still further and suggests that the main circulation pattern described above applies and the main stock is maintained by spawning in the vicinity of the South Orkney Islands. He suggests that the larvae are carried around the Weddell Sea in a clockwise direction to arrive back at the South Orkneys a year later. Some of these krill are carried around for a second year to spawn whilst the remainder drift out of this circulation pattern. This theory requires confirmation of the existence of the recurvature current (see Kumagori and Yanagawa 1958 and also Fraser 1936, p 165) and also a better understanding of total circulation in the Weddell Drift (see Deacon 1976).

In an extension of this cyclonic circulation theory Makarov (1972) has suggested that a similar system to that in the Weddell Zone could operate in the Ross Sea and Kerguelen Gaussberg ridge areas. Treshnikov (1971) describes six cyclonic gyres produced by prevailing cyclonic winds in coastal regions around the continent. These may represent areas of krill concentration as suggested by Beklemishev (1960).

In his review of distributional control one of the mechanisms that Marr (1962) postulates is the possibility that a population of krill in the Bellingshausen Sea continually releases larvae and adolescents that seed the East Wind Drift. During the course of successive generations this process is continued around the continent (see section on zooplankton in this paper). Such a theory although possible with water circulation pattern may not seem very likely in view of the known higher density of krill at the end of the cycle (Weddell Sea). However, this could be explained by the Weddell Zone itself being a self maintaining system as described above. Marr also mentions the possibility that larvae could be carried from the Weddell to the Bellinghausen Sea via the Bransfield Strait. Although there is no evidence for a water movement the full distance, there is evidence that water does enter the Bransfield Strait from the Weddell Sea (Clowes 1934). It has also been suggested (Everson 1976) that the Bransfield Strait itself might contain a self maintaining system.

The only area containing large concentrations of krill that has not so far been considered in this review is South Georgia. This has been considered as an area in which there is no successful spawning (Marr 1962) and as a result it is suggested that the krill population there has its origins in other regions. Because Weddell Sea water has been considered to flow along the northeast coast of the island (Deacon 1937) and also because the Southern Scotia Sea has been shown to contain large concentrations of krill the Weddell Sea is often considered as being the origin of most of the South Georgia Krill (Marr 1962). Recent research has suggested that the frontal zone between Weddell Drift and West Wind Drift now passes well to the south of South Georgia (Bogdanov et al. 1969, see also section on Hydrography in this paper). Under normal conditions therefore it would seem unlikely that Weddell Drift krill could be carried to South Georgia. Bogdanov and Solyanik (1970) in an attempt to explain how Weddell Drift krill could get to South Georgia show a good correlation between whale catches and the mean annual air temperature at South Georgia and Laurie Islands (South Orkneys). They suggest that Weddell Drift surface water is carried to South Georgia as a result of wind action on the surface. Unfortunately the cold years (which should have produced largest krill concentrations and thus whales)were linked to low whale catches. Maslennikov (1972) considers that krill concentrations in the vicinity of South Georgia are present in the boundary region between a north westerly flowing coastal current and a south easterly flowing current further offshore. In years when this circulation pattern is ill defined, commercial krill catches have been poor (Maslennikov et al. 1971). The impression is given in their paper that the water in this area is from the Antarctic circumpolar current and that Weddell surface water is mixed in the manner described by Bogdanov and Solyanik (1970). It has also been suggested that the South Georgia Krill have their origins in the Bransfield Strait or Bellingshausen Sea area (discussed by Everson 1976) although there is only circumstantial evidence to support this idea.

It is an interesting point regarding all of the proposed theories of distributional control that they all rely on fairly precise limitation in timing of development and flow of water masses. This is in complete contrast to the mechanisms of distributional control proposed for other members of the macroplankton which in general rely on the southerly movement of the warm deep water and northerly movement of the surface water. (Mackintosh 1937, Foxton 1956, Voronina 1968). For a mechanism such as this to be applied to krill it is clearly necessary to prove the existence of a seasonal vertical migration. Recent evidence has shown the existence of significant concentrations of krill down to 400m although as yet there is no year round coverage of observations to suggest that a seasonal pattern of vertical migration exists.

Mention has already been made of the possibility that krill could feed in deeper water on detritus. The fact that the main lipid store is not waxes (Bottino 1974), indicating continuous feeding (Sargeant 1975), would require the krill to be in deeper water during the winter. (With almost zero primary production in the surface water in winter the only food at that time is likely to be detritus at greater depth).

Clearly there is a need for more research to identify which of these mechanisms are of major importance in maintaining the enormous standing stocks of krill.

## 6.3 Growth and Life Span

Several authors have published curves of size at age for E. superba (e.g., Ruud 1932, Bargmann 1945, Marr 1962) (Fig 6.5) which indicate a seasonal pattern of growth during a two year life span to a maximum size of about 6 cm. More recently Mackintosh (1972) has produced curves of "local apparent growth" based on the catches from specific regions. His analysis does not include a consideration of the origin of the krill at a given location but relies purely on the size of individuals at the time and place of capture.

The simple two year life span has been questioned by several authors (Marr 1962, Ivanov 1970, Makarov 1971, Mackintosh 1972) who were all working from information from size frequency distributions. Recently Makarov (1975) has demonstrated the ability of female E. superba to spawn more than once thus indicating a longer life span than two years.

Marr (1962) because of the presence of a few specimens of abnormal size in his samples suggested that under certain conditions full sexual maturity and spawning may be delayed until the third year. This phenomenon has been reported in the related E. triacantha (Baker 1959). The degree to which the odd size group was present in Marr's samples was very small indeed. However, Ivanov (1970) with a much smaller number of samples detected an intermediate size group in a large proportion of samples from the Scotia Sea. He discussed this in detail and concluded that the intermediate size group represented an additional year class.

At the moment there is insufficient evidence available to conclusively prove that this intermediate size group does not represent an additional year class. Relevant information for both points of view will therefore be considered.

At the same time that Ivanov was preparing his results Mackintosh (1972) was in the process of reanalysing in detail the Discovery material. As a result of his analyses he showed the presence of an intermediate size class in most of the areas of dense distribution. For those areas where there are sufficient samples Mackintosh has drawn an expected growth curve which shows the intermediate group as being midway between the previously accepted first and second year groups. Mackintosh argues that since the previously accepted one and two year classes follow on in a smooth curve with fast growth in spring and slow growth in winter, the cause of the intermediate size group must be something other than an additional year in the normal life history. On the assumption that the intermediate size group is real and not an artefact of sampling, Mackintosh considers the possibility of an early or late spawning producing the effect. On balance he favours the theory that the intermediate group results from a second spawning later in the year (perhaps in May) but it should be emphasized that this conclusion is based on extrapolation from the start of the intermediate growth curve back for over a year. Makarov (1975, 1976) has shown that a significant proportion of the population spawn more than once, first time spawners release their eggs during the later part of the summer and second time spawners in the early part of the summer. The release of eggs at more than one time during the season of maximum primary production (and therefore growth) is likely to produce considerable blurring of the peaks in any size frequency distribution. Compared to E. triacantha the size frequency distributions for E. superba show relatively indistinct peaks (see Baker 1959, Marr 1962, Bargmann 1945, Ivanov 1970, etc.).

Mackintosh (1972) detected a correlation between the presence of the intermediate group and an above average temperature in the preceding half year (but not earlier). Although it is unlikely that a warmer year would cause a second spawning, it is possible that a warm year could result in a greater disparity in the growth of larvae resulting from spawnings at different times in the production season.

Makarov (1971) in a paper that also considers the conclusions of Ivanov (1970) is of the opinion that the extra size group does not represent an extra year class, but is a result of the mixing of krill from different sources. This suggestion is supported by the fact that the Bransfield Strait and South Georgia, areas of possible mixing, show the phenomenon quite frequently. Against the idea is the fact that the East Wind Drift zone also contains an

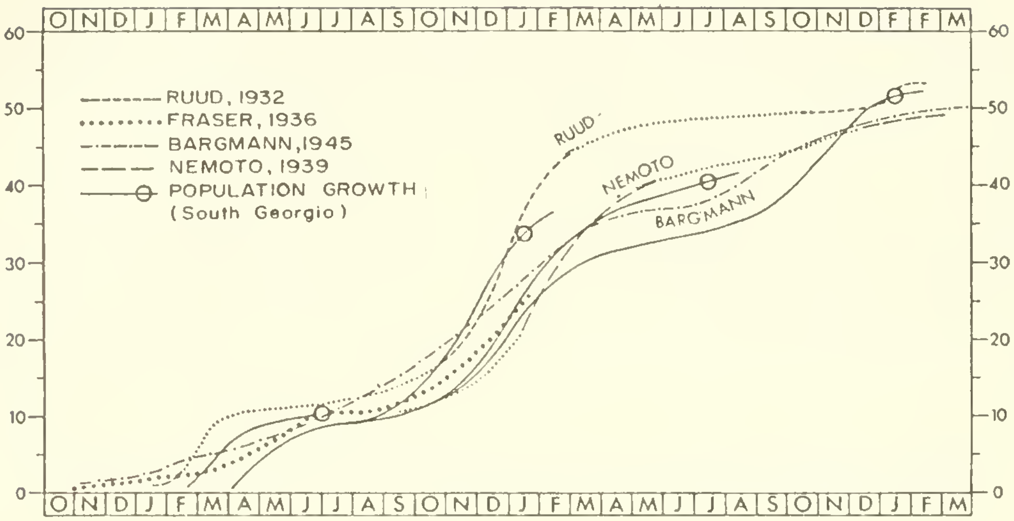

Fig.6.5 Published growth curves of krill (redrawn from Mackintosh (1972))

intermediate group, but on infrequent occasions and since the East Wind Drift has the slowest growing krill of all areas, the mixing would have to be with krill growing more slowly even than these which is clearly impossible.

Evidence on growth rate by other methods is at present inconclusive. Mackintosh (1967) McWhinnie (1976) and Clarke (1976) maintained several individual adolescent and adult krill in experimental aquaria and studied growth over several moults. In all cases growth increment was very small although both authors consider that their experiments were not a true reflection of growth in the natural state. The slow growth rate indicated by these experiments may indicate a slow growth rate in the wild. However, more sophistication in experimentation will be needed before this approach can be considered as giving a definitive answer to the problem.

In an analysis of growth curves for a variety of euphausiids Mauchline and Fisher (1969) have calculated average daily growth rates. These are summarised in Table 6.1.

Table 6.1 Calculated daily growth increment for a variety of euphausiid crustacea (Mauchline and Fisher 1969)

| Species | Life Time (Days) | Growth Increment (mg/day) |
|---|---|---|
| Thysanopoda acutifrons | 730 | 0.356 |
| Euphausia triacantha | 730 | 0.246 |
| Meganyctiphanes norvegica (Iceland) | 730 | 0.274 |
| (Clyde) | 730 | 0.427 |
| (Cadiz) | 365 | 0.383 |
| Thysanoëssa raschii | 730 | 0.155 |
| T. inermis (N.Iceland) | 1 095 | 0.132 |
| (S.Iceland) | 730 | 0.101 |
| T. longicaudata (Gulf Stream) | 365 | 0.032 |
| (Greenland) | 365 | 0.028 |
| T. longipes ♂ | 730 | 0.100 |
| ♀ | 730 | 0.141 |
| E. superba (Bargmann) ♂ | 730 | 0.849 |
| ♀ | 730 | 0.570 |
| (Ruud) | 730 | 0.808 |
| (Nemoto) | 730 | 1.340 |
| (Mauchline) | 730 | 0.822 |

The fact that the figures for E. superba are much higher than those for any of the other species may indicate that the lifespan used as the base (two years) is too short. A greater lifespan would reduce the daily growth increment to nearer the values for the other species.

A more detailed examination of the growth characteristics indicates that this high figure for daily growth increment may not be totally unexpected. In his analysis of growth in *E. triacantha*, Baker (1959) suggests that the larger size of *E. superba* is reached by a longer period of growth rather than by a faster average rate. Although at first sight this conclusion appears to be at variance with the calculated rates of Mauchline and Fisher, when considered in relation to season the similarities become apparent. The percentage increase in length during each month for the two species *E. superba* and *E. triacantha* has been plotted in Fig. 6.6 and the seasonal changes divided up into a series of growth stanzas leading to a first spawning. The changes occurring are tabulated in Table 6.2.

The difference in the spawning season of the two species means that by September or October, *E. triacantha* larvae are twice the length of *E. superba* larvae and it is only in the second growing season that *E. superba* become larger than *E. triacantha*. Bearing in mind that the *E. superba* were only present for the last part of the productive season stanza C is effectively the first production season that the young *E. superba* will experience. This is in effect the equivalent to stanza A for *E. triacantha*. Plotting growth during stanzas A and B for *E. triacantha* with those of *E. superba* for stanzas C and D (Fig. 6.7) show how similar growth is for the two species during this period.

Table 6.2. Subjective analysis of growth stanzas in Fig.6.7 leading to a first spawning in *E. superba* and *E. triacantha*

| Growth Stanza | Season | Growth in<br>*E. triacantha* | <br>*E. superba* |
|---|---|---|---|
| A | Summer<br>High primary production | Larvae present at start of season rapid growth throughout season | Larvae present at end of season |
| B | Winter<br>Very little primary production | Slow growth rate | Slow growth rate |
| C | Summer<br>High primary production | Moderate growth rate possibly due to development of gonads later | Fast growth rate throughout most of season |
| D | Winter<br>Very little primary production | Slow growth rate leading to spawning at end of period | Slow growth rate |
| E | Summer<br>High primary production | - | Slow growth.<br>Build up to spawning condition |

Although providing some evidence in support of the originally published growth curves this evidence should not be considered conclusive for several reasons. Firstly although it might be expected that similar species should grow in a similar way this does not necessarily follow. Secondly, [illegible] account has been taken of growth by larvae resulting from the early (normal for *E. triacantha*) spawning in *E. superba*.

The information related to growth in *E. superba* is summarised in Table 6.3.

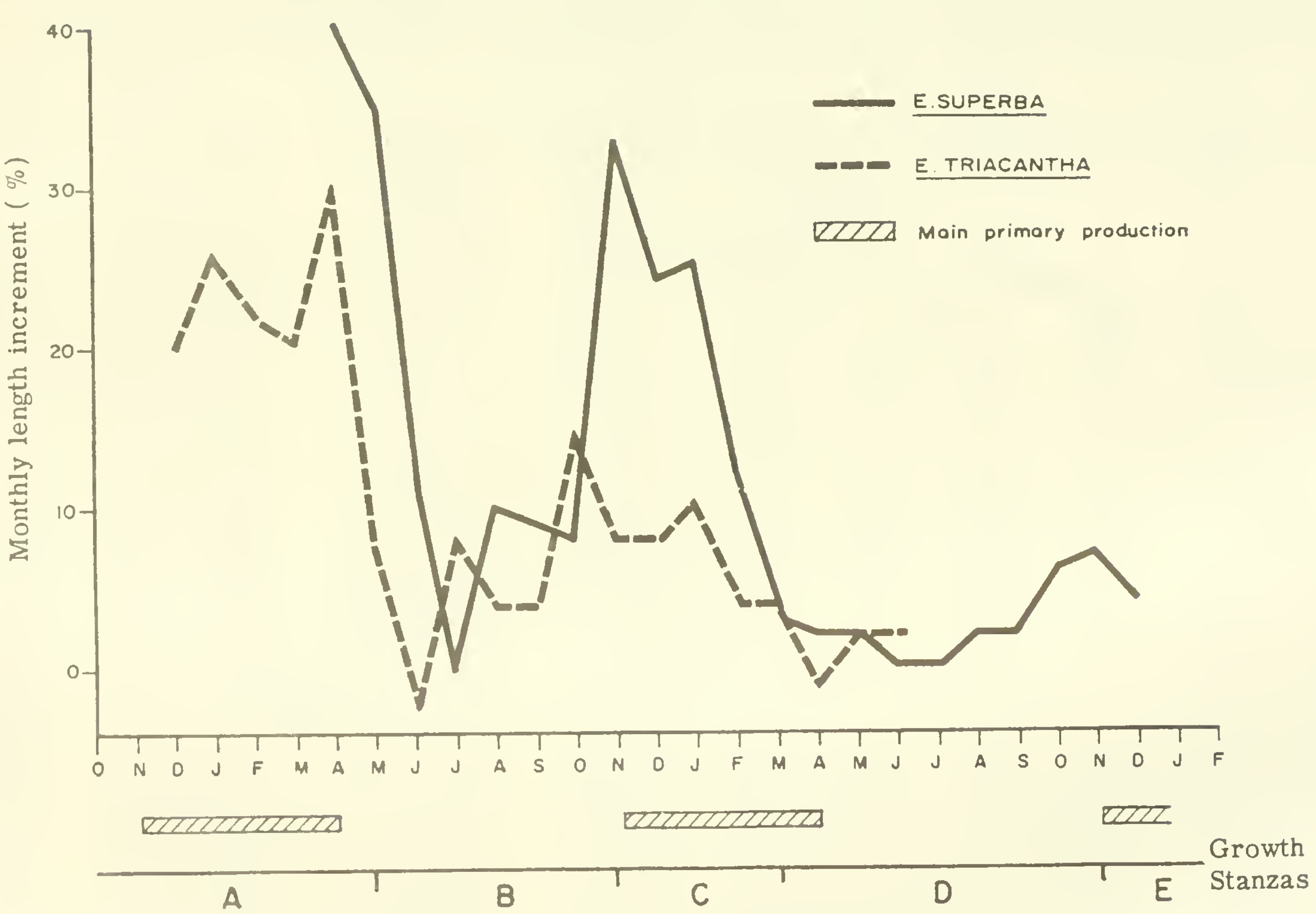

Fig.6.6 Seasonal growth of two species of euphausiid, related to the time of the main primary production. Growth is shown as the increment during the month, expressed as a percentage of the length in the previous month. Data for E.superba in the northern Weddell drift(from Mackintosh(1972)) and for E.triacantha(from Baker 1959))

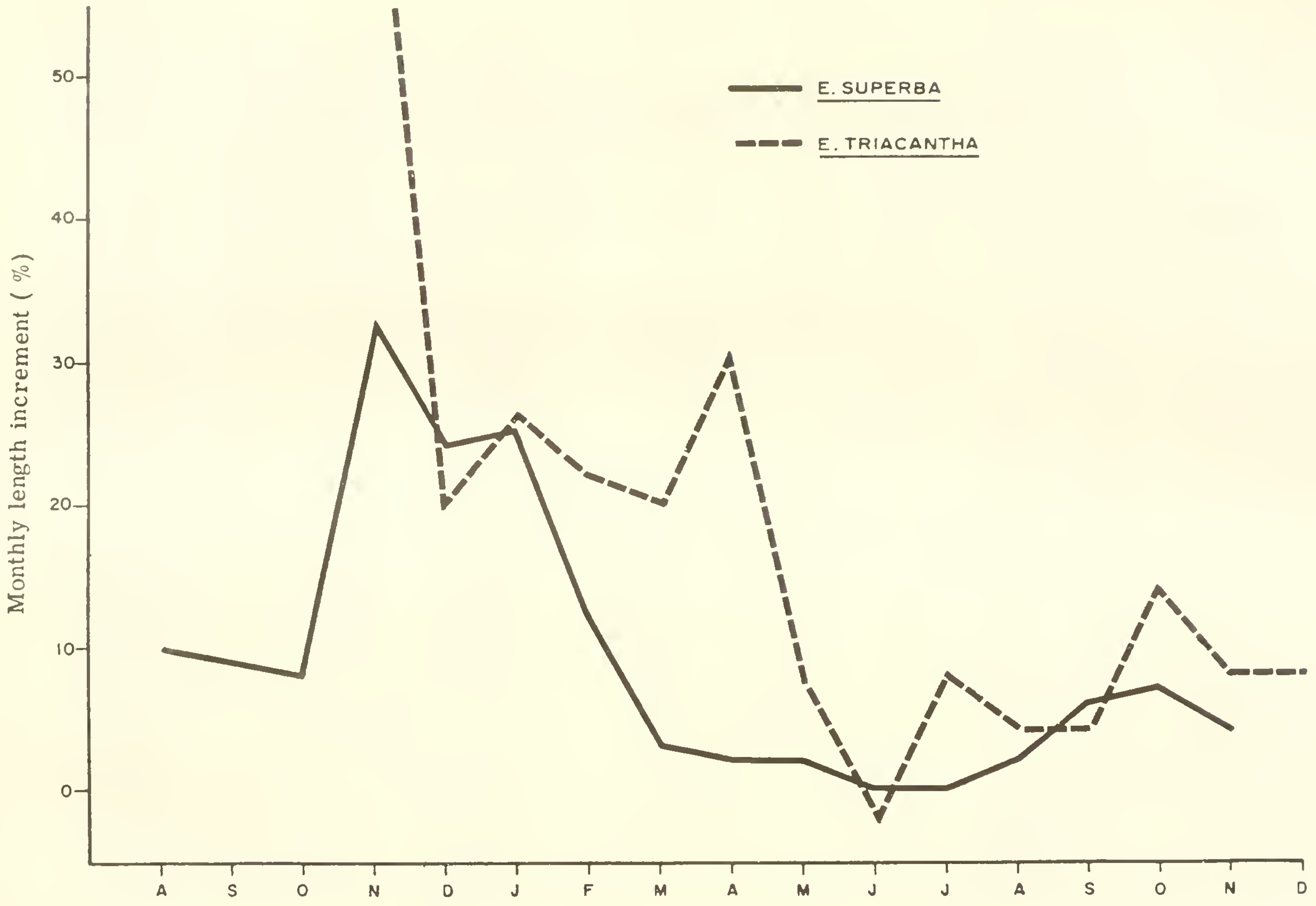

Fig.6.7 Comparison of growth in E. Superba in the second season of growth with that of E. triacantha in the season of spawning

Table 6.3. Summary of information related to life span in Euphausia superba

| Observations | Evidence for 2 years to first spawning | Evidence for more than 2 years to first spawning |
|---|---|---|
| Size frequency analysis of Bargmann, etc. | "Smooth" curve | "Intermediate" size group |
| "Intermediate" size group | Does not fit anticipated smooth curve | Additional peak or peaks in many size frequency distributions in summer |
| Growth rate based on two years to first spawning | Summer growth pattern similar to E. triacantha | Overall growth rate appears high |
| Laboratory growth experiments | Probably not valid for "natural" conditions | Measured growth rate very slow |

Recent work (reviewed in the section on Reproduction)has shown that a significant proportion of the population spawn for a second time although the growth increment in this additional year is only small.

The information that is available although far from conclusive indicates that the growth pattern originally described by Ruud (1932) and Bargmann (1945) is probably correct. There is however considerable doubt about this and the possibility that the intermediate size group does represent an additional year class has neither been conclusively proved nor disproved.

## 6.4 Reproduction

A good general description of the reproductive biology of euphausiids is given by Mauchline and Fisher (1969), whilst detailed specific information covering the main aspects of reproductive biology is available in Bargmann (1937) and Fraser (1936). The topics of particular interest in this review are spawning season, fecundity and the phenomenon of repeated spawning.

### Spawning season

It is now generally accepted that spawning by E. superba occurs at the surface (see Marr 1972, Fig. 30, Voronina 1974, Makarov 1974) during the summer months. In a brief review of published information on the precise spawning period Mackintosh (1972) suggests that it is at its peak in February and March although gravid and freshly spent females were found from November to April. In general he describes the spawning season as being earlier in the northern end of the range than nearer the continent and gives the following "best estimates" of mean hatching and spawning dates (Table 6.4).

The dates (Table 6.4) were calculated to provide the origins of growth curves from the different regions and are estimates based on the known spawning dates in the Weddell and East Wind Drift zones. Thus, although they are presented within fairly broad limits and are subject to local annual variation, they are useful at this stage as a first approximation.

Table 6.4. (From Mackintosh 1972) Mean dates for major spawning and hatching of E. superba

| Locality | Spawning date | Hatching date |
|---|---|---|
| South Georgia[1/] | 25 January | 3 February |
| Northern Weddell Drift | 31 January | 9 February |
| Scotia Sea | 20 February | 1 March |
| Central and Southern Weddell Drift | 5 March | 14 March |
| Bransfield Strait | 11 March | 20 March |
| East Wind Drift | 20 March | 29 March |

Working on samples collected in the vicinity of the South Orkney Islands (equivalent to Mackintosh's Scotia Sea area) Makarov (1973) describes spawning as occurring at the end of February and that the timing of the peak is very much dependent on temperature. In warm years he suggests the sea ice clears earlier thus allowing an earlier start to the growing season with a resultant earlier spawning.

The main purpose of Mackintosh's analysis of spawning date was aimed at providing an origin for the growth curves for results from different areas. He was therefore only concerned with the mean date of spawning and took little account of the several month variation in the observed dates on which eggs were found. Marr (1962) in considering the overall spawning season in the northern or Weddell zone did not consider spawning as a short-term outburst, as had been suggested by Ruud (1932), but suggested it occurred over the period November to March. The recent work of Makarov (1975, 1976) has indicated that individuals spawning for the first time do so late in the season (February, March) whilst those which live for a further year spawn for a second time during the November, December, January period. The release of eggs during most months of the production season will almost certainly result in a broad size frequency distribution for each year class (if year classes can be identified). This in turn could also result in the production of an intermediate size group (see section on growth) as has already been discussed. Clearly it is only when definitive spawning periods in given locations are identified and the development of the subsequent size groups are followed that it will be possible to subdivide the broad size frequency distributions and thus help in unravelling the growth story.

The information reviewed by Mauchline and Fisher (1969) indicates that euphausiids generally spawn in the spring or early summer and that by spawning at the end of the summer E. superba is an exception. It is however possible that originally the spring breeding season now identified by Makarov may have been the norm and that the late summer spawning has only recently evolved. No matter what the sequence of evolution it is probable that the two spawning periods represent a fail safe device in maintaining a high biomass.

## Fecundity

Estimates of fecundity are few and include a wide range of values as a result of different techniques in estimation. These are reviewed by Mauchline and Fisher (1969) who consider

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[1/] (N.B. There is very little evidence of successful spawning in the vicinity of South Georgia).

that for euphausiids in general the best estimation technique is that based on the calculated number of eggs whose volume is equal to half the mature ovary and that the ripe ovary occupies about 10% of the body volume. Makarov (1975) states that the eggs released amount to 34-39% of the body weight in E. superba which, assuming that weight is proportional to volume and that eggs have a volume of 1 x 10$^{-4}$ ml, indicates a very much higher fecundity. This estimate is in closer agreement with the results of Naumov (1962) who counted ripening eggs present in the ovary. The estimates are compared in Table 6.5. The figure of over 11 000 determined by Bargmann (1937) is probably an estimate of all the eggs at all stages present in the ovary rather than an estimate of the number that would actually be released. This figure has therefore not been included in the tabulated results.

Table 6.5. Fecundity of Euphausia superba. Data from Mauchline and Fisher (1969), Makarov (1975), Naumov (1962) and Nemoto et al (in press).

| Body Length | Body Volume | | No. of eggs (1 x 10$^{-4}$m (each)) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Equal to 50% ovary | Equal to 34-39% Body Volume | | Counted | |
| mm | ml | mg | Mauchline and Fisher | Makarov | Nemoto | Naumov | |
| 36 | | | | | | 2362 | |
| 38 | | | | | | 2655 | |
| 40 | | | | | | 3007 | |
| 41 | 0.62 | | 310 | 2110-2420 | | 3590) | |
| 43 | | | | | | 3520) | 3320 |
| 43.5 | | 851 | | | 3502(2222-7792) | ) | |
| 44 | | | | | | 2960) | |
| 45 | | | | | | 3480) | |
| | 1.0 | | | 3400-3900 | | | |
| | 1.6 | | 800 | 5440-6240 | | | |
| 46.7 | | 927 | | | 7146(2482-14086) | | |
| 50.3 | | 1507 | | | 8370(3889-13091) | | |

It is not clear what is the reason for the enormous variation in the estimated values of fecundity. The egg size noted by Naumov (1962) in the ovaries of the individuals he examined would indicate that the eggs released represent nearly 60% of the body volume. The release of such a large proportion of the body volume as eggs just prior to the winter season seems unlikely if the same individual is going to spawn a second time in the following spring. On the other hand the general figures derived by Mauchline and Fisher (1969), as they point out, are not always correct and in this context it may be that E. superba is an exception. There is therefore a clear need to identify what proportion of the eggs present in the ovary are released and also to generally improve the refinement of these estimations.

## 6.5. Swarming

The habit of E. superba of forming dense aggregations has been well known for a long time and because of the concentration of individuals within the swarms they are often thought of as ideal for exploitation. What is not clear however is the proportion of the total krill population that is present in the swarms nor the absolute density. The former point is vital to resource management and the latter to rational fishing.

In this context a swarm can be defined as a dense aggregation of individuals moving harmoniously and is probably the type of aggregation that will give a strong indication on an echosounder. A swarm may therefore be considered as the extreme case in terms of co-ordinated movement of individuals in a group. The other extreme would be independently random movements by individuals. Between these two extremes there almost certainly exist concentrations that are intermediate in terms of aggregation and organization.

Swarming has already been discussed briefly in the section on zooplankton where it was suggested that swarming was a result of some social behaviour pattern (as yet unidentified) working in areas of high average concentration (such as discussed in the section on krill distribution). The section which follows is a review of information on swarm formation and disintegration.

Marr (1962) concluded on the basis of analysis of plankton net samples that from hatching onwards the number of krill outside of swarms was negligible. Although Marr was well aware of the maximum density krill attained when swarming his definition of a swarm was not nearly as restricted as that given above.

Other authors have been more evasive on the point only mentioning swarms without making any firm comment on the proportion of the total population present in swarms. The observations of Pavlov (1969) and Shust (1969) indicate that swarming is a transient phenomenon related to food availability. These observations were based on the state of the gut in freshly caught animals, a method also used by Nemoto (1968). According to Pavlov when phytoplankton is abundant the krill spend part of the day actively feeding in the surface water until they are replete at which time they aggregate into swarms and sink. In one region in which Pavlov made his observations this cycle occurred twice in 24 hours. The cycle of swarming and dispersion was repeated in other areas although without vertical migration; Pavlov attributes this difference to one of size; adolescent krill, he suggests, migrate vertically whereas adult krill do not. Shevtsov and Makarov (1969), however, note that in the course of vertical migration the adult krill tended to be deeper and in fact on occasions formed a separate layer (detected by echosounder) beneath the adolescent krill; they make no comment on the causes of swarming.

Nakamura (1973) identified several types of krill aggregation and related their presence and formation to light intensity. He found the densest swarms at the surface on the darkest nights and when the light intensity increased the density decreased as the animals migrated down. The commonest pattern of aggregation that he identified was a layer generally within the range 30 to 100 m depth or about 20 m above the thermocline. The results of Ozawa _et al._ (1968) conflict with these observations and indicate surface aggregations in daytime; they were however a result solely of visual observations. Shust (1969) considered that the level of illumination (cloudiness) of the environmental factors he measured (wind, sea state, atmospheric pressure) was the most important although he considered feeding also to be of major importance.

The suggestions of Ruud (1932), Beklemishev (1960) and Bogdanov (1974) that turbulence and eddy currents are responsible for the formation of swarms is probably not valid on the above definition of a swarm but more likely applies to the formation of high average abundance. Marr (1962) and Naumov (1962a) suggested that some swarms were in part spawning concentrations. Although there does not appear to be any conclusive evidence (no catches have knowingly been made of krill in the act of spawning) Makarov (1973) has shown the presence of concentrations of ripe individuals during the spawning period; he does not, however, describe the concentrations as swarms as defined above. It has also been suggested that swarming is a result of increased buoyancy due to the increase in lipid content during the summer (Burukovskii 1967). Presumably this would be expected to have the effect of concentrating the krill into Langmuir cells as described by Stavn (1971) for _Daphnia_ although there is no evidence to suggest that for krill this does in fact occur.

The major factors that have been positively identified as being associated with swarming are therefore light and feeding activity. Reactions of planktonic animals to light have been well documented by Cushing (1951), Stasenko (1967) and Burukovskii (1967) describe krill being attracted to a red light source but moving away from a strong white light source while Ivanov (1969) has drawn attention to the luminescence of krill in swarms. Further information is clearly needed to identify a possible wide variety of reactions by krill to light.

The suggestion by Pavlov (1969) that krill swarm as part of a feeding cycle implies dependence to a great extent on food availability - the more food that is available the more rapidly the animals become replete and swarm. As mentioned earlier a direct result would be that swarms would tend to appear during the early summer and be most frequent in abundance during the summer peak of primary production. Hardy and Gunther (1935) showed that in the South Georgia area the densest concentrations of phytoplankton were not coincident with the largest concentrations of krill (or other zooplankton) (see Table 4.1).

This general pattern is confirmed by Avilov et al. (1969) who found the largest concentrations of krill in areas of the Scotia Sea where the mean biomass of phytoplankton was 1-5 $ml/m^3$. In areas where the mean biomass of phytoplankton was less than 0.5 $ml/m^3$ or more than 5 $ml/m^3$ they found few krill concentrations. This observation is not confirmed by Shust (1969) who reports numerous krill swarms in areas where the phytoplankton density varied from 0.1 to 8 $ml/m^3$. He does however relate duration and size of swarm to phytoplankton standing crop - swarms persisting longer in areas of high phytoplankton standing crop. It is possible that the inverse relationship reported by Hardy and Gunther (1935) and Avilov et al. (1969) is due to grazing effect whereby there is a time lag before the herbivores eat down the phytoplankton (Cushing et al. 1963 and Cushing 1975). The direct relationship in that case would be expected during the initial phytoplankton bloom in areas where overwintering herbivorous zooplankton concentrations occur. Although this explanation is not proven in this instance, it does fit the facts and therefore indicates that studies investigating this interaction, and thus by implication other factors that might control krill microdistribution, should take account of short-term changes.

## Swarm Size

Estimates of swarm size have been made by both visual observation and analysis of echosounder records. Marr (1962) published a series of drawings of the horizontal outline of several swarms that were observed near to the surface. These swarms were all quite amorphous in shape and varied in size from a few to several hundred metres across and were continually changing shape in an amoeboid fashion. Nemoto et al. (in press) describe surface swarms as being generally round or oval in shape and that some changed shape as a result of wind stress becoming more oval with the greatest axis at right angles to the wind direction.

A comparison of swarm size between areas is made by Nemoto et al. (in press) who considered that swarms in the Scotia Sea area were on average smaller than those in the Queen Maud Land area.

In the vertical plane swarm size has been mapped using echosounders. Certain of the small swarms are so dense that it is impossible to define the vertical size. However, where density within the swarm is lower, authors have mapped the vertical distribution and size of swarms. In an analysis of this type, Shevtsov and Makarov (1969) describe various patterns in the changing shape of swarms observed in the Scotia Sea. From their observations it appears that there are a few common patterns throughout the area. The following types of vertical movement and configuration are described in Table 6.6.

Formation of two layers (Table 6.6) during the day and amalgamation at night with a tendency for adult krill to be at the deeper levels seem fairly standard. A much greater vertical movement was observed by Mohr (1976) who, using an echosounder, followed a concentration of krill in the vicinity of the South Sandwich Islands for 6 days in April 1976. At midnight the krill were massed in the top 20 m but by 0600 hours they had migrated to a depth of 70 - 110 m, to slowly migrate back to the surface during the following 10 to 12 hours. Since all these observations were made in a fairly brief period of time during one season, more information will be required to amplify these observations and conclusions.

Table 6.6 Information on the vertical range of krill swarms
(From information in Shevtsov and Makarov)

| Locality | Depth Range (m) of: | | | | Composition and other comment |
|---|---|---|---|---|---|
| | Upper layer | | Lower layer | | |
| | Day | Night | Day | Night | |
| Northern Weddell Sea | | | | | 2 Layers day time; one layer night, nearer surface. More adults with increasing depth |
| Northeast of S. Orkneys (a) | 10-30 | | 30-60 | | One layer at night. Catch mainly adults. |
| (b) | 15-30 | (10-40) | 40-70 | | One layer at night. Mainly juveniles near surface. Mainly adults at depth (200-400 m). |
| S. Orkney<br>S. Sandwich | 10-15 | 10-15 | | | Mostly juveniles |
| West of Sandwich | 10-20 | 20-45 | 40-80 | | Surface swarms also. Few mature krill. |
| N.E. of South Georgia | 15-40 | | 50-100 | | Few adults |
| S.W. of South Georgia | 40-60 | | 40-60 | | Few adults, no vertical migration. |

Swarm density

Several authors have published estimates of the density in terms of number and weight of krill within swarms. These are summarised in Table 6.7.

Most of the estimates (Table 6.7) of swarm density were made by means of acoustic fish-finders in conjunction with actual catches. There are clearly several sources of possible error in this type of estimation. Although the echosounder may give some indication of the vertical extent of the swarm it will give no indication of its lateral size; also, it is often difficult to confirm that a particular acoustic indication resulted in a particular catch.

The two estimates given by Marr (1962) are based on separate observations. The figure of one per cubic inch is based on the density estimated by an observer looking vertically down into a swarm from above. The figure of one per eight cubic inches was calculated from a single lateral haul in a large swarm (the net was towed for 36 sec at $1\frac{1}{2}$ kt through the swarm). Assuming a mean weight of one gramme per individual, this represents a density of about $6 kg/m^3$.

Table 6.7 Estimates of krill density in swarms

| Density | | Reference |
|---|---|---|
| Numerical | By Weight | |
| 1 per in.$^3$ 1 per 8 in.$^3$ | | Marr 1962 |
| | 10 - 16 kg/m$^3$<br>up to 15 kg/m$^3$ or more | Moiseev 1970<br>Makarov _et al._ 1970 |
| | generally up to 5 kg/m$^3$<br>max. 6-33 kg/m$^3$ | Nemoto and Nasu 1975 |
| 2000 - 8000/m$^3$*<br>Max. 40 000/m$^3$ | mean 1.5 kg/m$^3$ | Nemoto _et al._ (in press) |

* Absolute range 521-49,153

As a first approximation therefore the acoustic estimates largely confirm those from plankton hauls. From the point of undertaking fishing operations it is clearly possible to detect krill concentrations using echosounders. The magnitude of any diurnal vertical movement is likely to be of little consequence in catching technique. However, greater sophistication is required to quantify echo sounder indications in order to use them for estimation of standing stock or as "ground truth" for estimation by satellite imagery.

## 6.6 Food and Feeding

An extensive study of the food organisms found in the stomachs of a large sample of _Euphausia superba_ was made by Barkley (1940). The species list that he gives is largely confirmed by the observations of Hart (both lists are discussed at length by Marr 1962, pp. 172-176). While there are local differences in the occurrence of the various species (see also Hustedt 1958, Nemoto 1968, Kawamura, in press) the diatoms clearly predominate from these analyses. The preponderance of diatom remains is generally thought to result from the relative indigestibility of the siliceous frustules and therefore probably does not represent the true situation (see discussions by Marr 1962 and Mauchline and Fisher 1969) and although the feeding appendages are adapted to a herbivorous diet it seems clear that, when necessary, representatives of other groups can be taken. Mauchline and Fisher (1969) list the following groups as being represented in the diet:-

Algae, Diatoms, Dinoflagellates, Tintinnids, Radiolarians, Foraminifera and Crustacea.

In addition, Pavlov (1971) increases the list to include detritus and in extreme cases cannibalism. As already mentioned with regard to distribution detritus may well represent a major part of the diet in winter although there are no results to confirm this.

The only information available on diurnal feeding cycles is that of Pavlov (1969) who related the occurrence of swarms, feeding and food availability, (see section 6.5). It is not however clear to what extent these results are typical of the Southern Ocean as a whole or how they vary seasonally. Since the presence of certain diatoms in the guts of krill can have adverse effect on the quality of products made from them there is clearly a need for more study in this field.

## 6.7 Production and Biomass

The extreme variability in the density of krill caused mainly by its swarming habit has presented enormous problems in estimating biomass and production. There are quite a large number of papers giving estimates calculated both by direct and indirect means and these will be considered along with the major sources of error.

Based on visual observations from the deck of RRS William Scoresby and assuming a density of one individual per cubic inch in the top yard of the water column, Marr (1962) estimated a mean biomass of 2.5 g/m$^2$ for krill. In the same paper he recalculates the biomass using the results of Heyerdahl (1932) for mean weight and gets a figure of 29-28 g/m$^2$. The possible error in these estimates is enormous since the area under consideration is 500 yards on either side of the ship's track and swarms are assumed to be one yard deep. These rough calculations presented with great reserve, as Marr puts it, may be, he thinks, representative of the East Wind and Weddell Drift zones. Assuming that this area is about half that described by Mackintosh and Brown (1956) as south of the Antarctic convergence the total biomass is 521 million tons (based on 29-28 g/m$^2$) or 44.5 million tons (based on 2.5 g/m$^2$). Marr, basing his reasoning on the probable consumption of krill by whales is of the opinion that the higher figure is the more reasonable. This is the only direct estimate I have so far come across that is supported by calculation and yet even in this case the figures are presented within very broad limits since they are calculated by extrapolation from a relatively very small area that was at the time seen to be unusual.

In an analysis based on echosounder survey and fishing catches, Nemoto et al. (in press) have estimated standing stock as being from 0.5 kg/m$^3$ to 30 kg/m$^3$ although they do not indicate how these figures apply to the total Southern Ocean.

Makarov and Shevtsov (1972) quote a range of 953 to 1 350 million tons for the biomass of krill (abstract only seen) while Gulland (1970) estimated the total zooplankton biomass to be about 10 g dry weight per square metre or 150 million tons for the whole Antarctic and assumes that 50% of this is krill. Based on Gulland's estimates the krill biomass is therefore 75 million tons dry weight, or perhaps 750 million tons wet weight. The figure of 50% for the proportion of krill in the zooplankton is open to question as Voronina and Naumov (1968) found that Euphausiids made up only 7.6% of their zooplankton catches. However, since their nets may well have missed a significant proportion of the Euphausiid population this figure cannot be taken as firm even though it is based on a large number of observations.

To estimate production from these biomass figures, a conversion rate of 1:1 has been suggested (Gulland 1970, Hempel 1970) based on a mean life span of one year. Allen (1971) has questioned this ratio and by comparison with mortality rates in other Euphausiids (there being no information available for E. superba) he suggests that the production is between 1.8 and 2.1 times the biomass with the lower figure the more likely. On this basis the krill production is 940 million ton/year from Marr's figures and 1 350 million ton/year based on Gulland's figure.

Indirect estimates of biomass and production have been made based on both higher and lower trophic levels. First of all considering estimates based on primary production, Hempel (1970) quotes results from localities all round the Antarctic continent for annual carbon fixation of 43 g C/m$^2$ (Currie 1964), 84 g C/m$^2$ (El-Sayed 1967) and 100 g C/m$^2$ (Ryther 1963) and suggests that since the measurements tended to be in the richer areas a figure of 50 g C/m$^2$ is a reasonable approximation. Taking a conversion ratio of carbon to fresh weight of 1:10 primary production is estimated as 10 000 million ton/year (Gulland 1970). There does not appear in the literature any firm figure for the conversion rate of phytoplankton by Euphausiids although a 10% figure has been used (Gulland 1970). Chekunova and Rynkova (1974) estimate that in growing to 1.5 g an individual consumes 60 g of phytoplankton. This gives a conversion ratio of 1:40, but since this is an average figure for an individual to achieve a maximum size the mean population figure may well be nearer the 1:10 ratio generally used 1/. On the basis that krill represents between 10 and 50% of the total herbivorous zooplankton, the production figures calculated are given below:

| | | Conversion Ratio Phytoplankton: Krill | |
|---|---|---|---|
| | | 1:10 | 1:40 |
| Krill as Proportion of Herbivorous zooplankton | 50% | 500 | 125 |
| | 10% | 100 | 25 |

Estimates of krill production (millions of tons per annum) calculated on the basis of total primary production of 10 000 million ton per annum.

Calculations of the amount of krill eaten by whales have been made by several authors and more recently the same calculation has been made based on the estimated initial whale stocks to give an estimate of "surplus" krill.

Independent estimates of krill consumed by whales are given in Table 6.8.

Laws (in press) has also estimated the amount of krill consumed by Crabeater, Leopard, Ross and Fur Seals at 53 920 thousand tons each year of which about 99% is taken by the Crabeater Seal.

Estimates of krill consumption by birds have been made by Prévost (in press) and Croxall (pers. comm.). Both agree that the major consumer is the Adelie Penguin (Pygoscelis adelie) which it is estimated takes about two-thirds of the 14.7 to 20.3 million tons total eaten by birds.

There are no estimates in the literature for krill consumption by other groups such as fish and squid although it is quite likely that either or both could be major consumers. Laws (in press) estimates that sperm whales consume annually 4.6 million tons of squid which, assuming they feed predominantly on krill and assuming a ten to one conversion ratio, would account for 46 million tons of krill. The same calculation applied to the estimates based on squid eaten by the total initial whale stocks would account for 102 million tons of krill per annum.

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1/ In their paper Chekunova and Rynkova give a detailed breakdown of food consumed at monthly intervals during the lifespan. In the absence of realistic size frequency information it is not possible to produce a better conversion ratio.

Table 6.8 Estimates of Annual Consumption of Krill by Whales

| Author | Krill eaten by initial whale stock Ton x $10^6$ | Krill eaten by present whale stock Ton x $10^6$ | Potential "Surplus" Ton x $10^6$ |
|---|---|---|---|
| Marr (1962) | 38 | - | - |
| Studentskiy (1967) | - | 270 | - |
| Kasahara (1967) | | 24 - 36 (Fin Whale) | |
| Zenkovich (1970) | 150 | - | - |
| Mackintosh (1970) | 120 - 170 | (10)**** | 100 - 150 |
| Hempel (1970) | 45 - 60 | - | - |
| Gulland (1970) | >50 | - | - |
| Nemoto (1970)* | 77 | - | - |
| Doi (1973)** | 200 | - | - |
| Lyubimova *et al.* (1973) | (800 - 5000)*** | - | - |
| Ohmura | 250 | (40)**** | 100 - 200 |
| Laws (1977) | - | - | 153 |
| Laws (in press) | 190 | 43 | 147 |

Results where all the factors in the calculation have been given are underlined

* Cited by Nemoto and Nasu 1975 but reference not given

** Cited by Nemoto and Nasu 1975

*** May refer to total krill biomass

**** Calculated from his results

N.B. (There is a much longer list of references quoting krill consumption by whales but those seen are derived from those tabulated).

The total estimated production based on consumption by predators is summarized in Table 6.9.

Clearly, in spite of the enormous uncertainty attached to these estimates (Table 6.9) the total amount of krill consumed by predators is large, thus confirming the estimates by other methods.

Table 6.9. Estimated consumption of krill by major predators 1/ (for detailed breakdown see relevant consumer section)

| | Estimated consumption of krill prior to whaling million ton/year | Estimated consumption now million ton/year |
|---|---|---|
| Whales | 190 | 43 |
| Seals | (?) | 64 |
| Birds | (?) | 15 - 20 |
| Squid | (?) | (100 ?) |
| Fish | (?) | (?) |
| TOTAL | > 190 | > 200 |

## 6.8 Exploitation

### Annual catch

Exploratory fishing for krill has been in progress now for several years. Solyanik (1960) obtained a small catch of krill using a small pelagic net from a whaling ship. Catches from the subsequent krill fishing expeditions are shown in tables 6.10, 6.11 and 6.12.

In addition to these exploratory fishing expeditions there are catches reported in FAO Yearbook of Fishery Statistics Vol. 40 (FAO 1976) that probably refer to krill ("Marine Crustacea,unspecified " taken from areas adjacent to the Fisheries Statistics Antarctic regions). These figures, together with actual krill catches recorded in the Yearbook, are set out in Table 6.13.

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1/ A single estimate of standing stock of between 1.5 and 5 milliard tons is given by Bogdanov (1974). Since this figure was calculated on the basis of consumption by whales and other consumers it probably refers to production rather than biomass. Even allowing for the production/biomass factor proposed by Allen (1971) this figure is still enormous compared to all other estimates of the resource. In the same paper Bogdanov estimates the standing stock in the Southern Scotia Sea in 1967 as 5 million tons, half of which is in the zone of mixing between Weddell Sea and circumpolar water. Also, he estimates that at South Georgia the stock is 0.7 million tons. These estimates were made directly and although the precise method employed was not stated it was probably using echosounders and commercial catch data.

Table 6.10 Exploratory fishing by vessels of the USSR

| Vessels | Season | Catch (tons) | Reference |
|---|---|---|---|
| Muksun | 61/62 | 4 | Burukovskii and Yaragov (1967) |
| Muksun | 63/64 | (70)[1] | Stasenko (1967) |
| Academik Knipovich) | 64/65 | 185 | Nemoto and Nasu (1975) |
| Orehova, Obdorsk ) |  | 121 |  |
| Academik Knipovich | 66/67 | ? |  |
| Academik Knipovich | 67/68 | >140 | Ivanov (1970) |

Table 6.11. Exploratory fishing by Japanese vessels

| Vessels | Season | Catch (tons) | Reference |
|---|---|---|---|
| Chiyoda-Maru | 72/73 | 59 | Nemoto and Nasu (1975) |
| Taishin-Maru No.11 | 73/74 | 646 | Nemoto and Nasu (1975) |
| Taishin-Maru and | 74/75 | 1 140 | Anon (1976) |
| Aso-Maru |  | 1 460 |  |
| Exploratory Vessel) | 75/76 |  |  |
| Commercial Vessel ) |  | 5 000 | Anon (1976) |
| Planned Catch | 76/77 | (10 000) | Anon (1976) |

Table 6.12. Exploratory fishing by other nationalities

| Nationality of Expedition | Season | Catch (tons) | Reference |
|---|---|---|---|
| Chile | 74/75 | 60 | Anon 1975 |
|  | 75/76 |  |  |
| West Germany | 75/76 | 400 | Anon 1976 a |
| (2 vessels) | (77/78) |  |  |
| Poland<br>(2 vessels) | 75/76 | ? | Anon 1976 b |
| Other Asian Countries | 76/77 | ? | Anon 1977 |
| Norway | 76/77 | Small | Anon 1977 a |

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[1] The total catch in his tables is only 23 tons

Table 6.13. Catches of krill in area 58, and of unspecified Marine Crustacea by certain countries in areas 41, 47, 51, 57 and 87

metric tons

| Year / Country | 1969/70 | 1970/71 | 1971/72 | 1972/73 | 1973/74 | 1974/75 |
|---|---|---|---|---|---|---|
| Krill | | | | | | |
| Japan | - | - | - | - | 643 | 1081 |
| U.Marine Crust | | | | | | |
| USSR | 100 | 1300 | 2100 | 7400 | 4412 | 6965 |
| Chile | 1900 | 1200 | 4400 | 2600 | 821 | 821 |

In addition to these figures McWhinnie (1974) and El-Sayed (1975), estimate that a total of 200 000 tons of krill have been taken per season in recent years. This figure is not supported by further evidence and it probably refers to total landings of krill and fish (see section on fish exploitation).

From the foregoing it is evident that the present fishery, taking as it does about 20 000 tons per year, is still only having minimal effect on the resource. However, all of the nations presently involved in exploratory fishing are capable of mounting quite a considerable effort and thus increase the size of the fishery very quickly.

Catch Rates

Development of a fishery based on a novel resource means that exploratory fishing operations may well meet with only limited success initially. In the early stages there have been problems with detection as well as gear operation and although a critical review is outside the terms of reference for this paper information on the development of the fishery is set out in Table 6.14.

Although the figures of 10-12 ton/hr by "special midwater trawl" for the early stages of commercial fishing by USSR in the Scotia Sea (Lyubimova et al. 1973)[1/] appear exaggerated, the evidence of the West German expedition suggests that catch rates of this order are now reasonable.

## 6.9 Stock Assessment

### Some Theoretical Considerations

The build up in sophistication of fishing technique over the past few years clearly indicates the possibility that a large scale fishery could be established in a relatively short period of time. Detection and catching methods have now reached the point when an excess of material can be provided for currently available processing operations. The main obstacles to the expansion of the fishery now lie in product development and marketing and these are receiving increasing attention. Any of the nations currently involved in fishing for krill (USSR, Japan, Federal Republic of Germany, Poland, Chile) could either on their own or with outside help solve the processing and marketing problems and vastly increase their present catch so that a total catch of a million tons or more is a distinct possibility in the immediate future. Even allowing for the fact that this is a small figure in comparison to the estimated krill production, once fisheries of this size are established they tend rapidly to expand to their fullest capacity. Therefore even though it is not certain that the krill fishery will expand it is necessary to formulate a management plan now to enable the needs of conservation and capital investment to be fulfilled. There is clearly a need therefore for:

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[1/] See also Kryuchkova et al. 1971.

Table 6.14. Information on fishing activities for krill

| Vessel Nationality | Year | Gear | Catch Rate Ton / Haul | Detection Method | Notes | Reference |
|---|---|---|---|---|---|---|
| Muksun<br>(USSR) | 61/62 | MWT | 0.13 | Visual/ Random? | 3 Ton Total | Burukovskii & Yaragov 1967 |
| | | Side Trawl Conical Net<br>" | 0.07 | | 150 kg/12 Hauls | Stasenko 1967 |
| | 63/64 | 31m MWT | 0.13 | Visual/ Random? | 107 Hauls | Stasenko 1967 |
| | | Side Trawl | 0.025–0.5 | | Night (Max. hauls 0.75 t) | |
| | | | 0.65 | | Day (Max. catch 2.5 t average of all hauls 0.6 t | |
| Orechova Obdorsk (USSR) | 64/65 | 17.5 m | 0.7 | | Slightly higher catch rate when pair trawling | Nemoto & Nasu 1975 |
| Akad. Knipovich (USSR) | 64/65 | 31m MWT | 1.7 | E/Sounder | At surface | Groisman, et al. |
| | | | 0.5 | | Midwater | |
| | 67/68 | MWT | 2 | E/Sounder | Max. 7 t/haul | Ivanov 1970 |
| Chiyoda Maru | 72/73 | Side Trawl | 0.1 | Visual | 251 Hauls | Nemoto & Nasu |
| No.11 Taishin Maru<br>(Japan) | 73/74 | 17.3 m MWT | 1 | | 691 Hauls | |
| | 74/75 | | 2.3 | E/Sounder | | Nasu (in press) |
| | 75/76 | | 4.6 | E/Sounder | | " " " |
| Weser.<br>(German Fed. Rep) | 75/76 | MWT | 24.1 t/h<br>15.6 t/h | E/Sounder | 7 hauls N.E. of S.Georgia. East of S.Georgia (largest haul 35 t in 8 min). | Kock & Neudecker 1977 |
| | | | 28.8 t/h | | Between S.Orkney and S.Georgia | |
| | | | 8.5 t/h | | N.W. of South Sandwich | |
| | | | 2.5, 25 | E/Sounder | Two experimental deep hauls | Fischer 1976 |

Note: A purse seine has been tried by Japanese workers with very limited success (Nasu 1974)

a. Sound scientific information on the state of krill stocks.

b. Advice on the effect of exploitation on the stocks of krill and its consumers and prediction of anticipated changes as a result of different fishing strategies.

c. International agreement on management plans resulting from a and b.

d. Implementation of management plans.

The known reliance by most of the whales, seals and birds indicated in section 6.7 plus the probable reliance of a significant proportion of the fish and squid stocks on krill indicates that, as far as management decisions are concerned, krill cannot be considered in isolation. These interactions are discussed later in Chapter 10 in which the conclusions based on an assessment of each single resource are brought together. The remainder of this section will be concerned with stock assessment as related solely to krill.

A convenient, and often used, estimate for the maximum size to which a fishery should be permitted to develop is the maximum sustainable yield (MSY). This may be defined as the greatest constant amount of the resource that can be extracted annually (and therefore by implication be replaced at the same annual rate) in the long term. This does not mean that an aim of management is to achieve this level of exploitation, but rather to define an upper limit beyond which a long term fishery should not develop. In the case of krill because of the wide range of consumers in addition to man that are utilizing krill the fishery could not develop to the theoretical MSY without causing considerable imbalance in the ecosystem.

As a first approximation a "SCHAEFER" type model can probably be used. This requires information in two of three forms: catch, effort and biomass. Of these three the catch is the simplest to determine. Estimation of fishing effort presents several problems in deciding on a realistic index. The present trend in the fishery suggests that any major expansion will be as a pelagic trawl fishery. The fishing effort may be divided into a series of components each of different relative importance (Table 6.15).

Table 6.15. Major components of fishing effort in a trawl fishery for krill with their relative importance.

| Fishing Effort Component | Relative Importance |
|---|---|
| 1. Gear | |
| a) Size of net | Moderate importance, depends on engine power. |
| b) Gear saturation (includes saturation of handling capacity) | Likely problem since present evidence suggests catching capability may exceed processing capacity. |
| 2. Vessel | |
| a) Size | Low importance. Only relatively large vessels may be able to operate in Southern Ocean. |
| b) Power | Moderate importance since technique is essentially aimed trawling. |

Table 6.15 (continued)

| Fishing Effort Component | Relative Importance |
|---|---|
| 3. Fishing Time | |
| a) Catching time | Low importance since catch more dependent on fish finding equipment. |
| b) Search time | Great importance due to extreme patchy nature of resource. |
| 4. Fishermen | |
| a) Skill | Moderate importance. |
| b) Within fleet communication | Moderate importance. |

Of these components probably the most useful as far as providing a reliable index of fishing effort are the power of the vessel combined with an indication of fishing time that takes account of "idle time" caused by gear/vessel saturation.

At the moment there is no well-established method of monitoring the changes in abundance of krill, in either relative or absolute terms, although suitable techniques are being developed. Since it is a member of the zooplankton, krill can be caught by specially designed quantitative nets such as the Rectangular Midwater Trawl with 8 square metre mouth (RMT 8) developed by the Institute of Oceanographic Sciences (U.K.) and used with success by the Federal Republic of Germany's Antarctic Expedition. This type of direct method is very time consuming and expensive in ship's time and is therefore not an efficient method of estimating standing stock over the whole region. Quantitative net hauls can be made to identify echosounder indications and thus form the basis of a remote sensing survey. The dense concentrations of krill when they occur near the surface may also be detected by satellite photographs. Both the remote sensing methods mentioned above rely on the occurrence of swarms and since these are almost certainly varying in occurrence, depth and density with season there is clearly a great deal of scope for biological investigations in this field.

The next stage in resource assessment will almost certainly be the design and application of an analytical model with the intention of adding increased precision to the estimates and predictions. The classical Beverton and Holt type model assumes constant recruitment and also that the level of natural mortality remains constant and independent of fishing intensity. For a short lived species such as krill it is very likely that there will be large year to year fluctuations in recruitment caused by both physical and biological variation. (There is no evidence to either prove or disprove this suggestion - a situation that is likely to remain until some reliable estimates for standing stock are available.)

Natural mortality is, for convenience, generally assumed to be more or less constant and independent of fishing. However, for a short-lived animal (with possibly only one year class in the exploited population) in the centre of a food chain this assumption is almost certainly not valid.

Natural mortality can for convenience be attributed to two causes: consumption by predators and natural death direct to decomposers. The mortality due to predation can be further subdivided depending on whether a given stock of predators take a fixed quantity (so that the rate decreases as the prey stock increases) or exert a fixed rate of predation (so that the quantity increases as the prey stock increases). These correspond, somewhat roughly, to predation by warm-blooded and cold-blooded predators respectively.

On the assumption that krill production is independent of fishing, the yield from a fishery will be largely at the expense of natural mortality as is indicated in equation (A) below:

$$\frac{dN}{dt} = -ZN$$

$$= -FN - C - M_c N - M_d N \qquad \text{(A)}$$

N = Population Size

Z = Coefficient of total mortality

F = Coefficient of mortality due to fishing

C = Consumption by warm blooded predators (N.B. dependent on consumer stock size. Consumption/individual varying with consumer density)

$M_c$ = Coefficient of mortality due to other predators

$M_d$ = Coefficient of mortality leading directly to decomposers

Intuitively it is to be expected that fishing will first of all be at the expense of $M_d$ and then reduce the proportion of $M_c$. Since C is for the most part dependent on the predator population size and the duration of the feeding season, this could be the least affected by fishing. Although this conclusion is tentative it does indicate the need for consideration of the effects of predators in a predictive model of a krill fishery.

Just as predation is an important factor in considering a krill fishery, it is equally important in studies of the predators themselves. This applies whether the predators themselves are likely to form the basis for a fishery (in which case the need for such an analysis is obvious) or not (in which case the information will be useful in understanding ecosystem dynamics). In order to gain some insight and begin to understand the interspecific interactions it is useful to consider the situation of an intensive krill fishery in one limited area. The effect that this fishery has on the krill consumers will depend on the size of the Unit Stock being fished. The hypothetical nature of much of the information on the control of krill distribution shows that at this stage it is impossible to define more than one management stock (Mackintosh 1973 indicates the possibility of there being several although the information is not conclusive) and, bearing in mind that there may exist several stocks it is worth considering the possible magnitude of any changes in relation to the stock size. On the assumption that fishing would be restricted to one defined area a few of the effects that it may be possible to quantify are listed in Table 6.16. The effects themselves are described in subjective terms because the effects may differ from area to area. For the purposes of the krill fishery these effects could indicate changes in the krill stocks which would thus add weight to conclusions based on direct observations. The changes in consumer stocks also form part of a much larger family of observations concerned with ecosystem modelling, a subject discussed in a later section.

## Stock Assessment

### Some Practical Considerations

The fragile nature of euphausiids means that any individuals which pass through the meshes of a trawl net are unlikely to survive so that irrespective of whether the krill

Table 6.16. Effects of an intensive krill fishery in one limited area.

| | One large 'Antarctic' Unit Stock | Several Unit Stocks defined by area. Fishing in one only |
|---|---|---|
| Effect on Stock Assessment Parameters | | |
| a) Growth | Small | Probably small |
| b) Mortality | M - no change<br>F - small | M - may change<br>F - large |
| c) Biomass | Small | Significant reduction subsequent to start of fishing |
| Effect on Natural Consumer | | |
| 1. Species linked closely to fishing area (e.g., Breeding Birds) | | |
| a) Intensive fishing prior to critical predation period each season | Significant in fishing area, elsewhere minimal | Significant. Increasing effect with time to eventually level off |
| b) Intensive fishing during and after critical predation period | Small effect | Significant in subsequent years |
| 2. Species not tied to fishing area (e.g., whales) | | |
| a) Heavy fishing before normally present in area | Small overall effect | Reduced density (i.e. feeding elsewhere) |
| b) Heavy fishing during and after normal presence in area | Zero or slight reduction in density | Slight reduction in short term<br>Major reduction in long term |

are retained by the net (or are of a size suitable for processing) none that enter the mouth of the net will survive. The effect of this is that unless trawls can be aimed at swarms containing individuals of the desired size the fishery will be totally unselective as regards size of krill caught. One of the objectives of management must clearly be to ensure that sufficient individuals spawn to maintain the population. This implies that the fishery should be based on the largest sized individuals in the population.

The presently developing fishery is largely based on fishing at swarms identified on echosounders. However at the moment it seems unlikely that the presently developed acoustic techniques can discriminate between large and small animals and unless there is shown to be a requirement for processing to only use large individuals it seems unlikely that sufficient funds will be channelled in this direction for developing the necessary technology. There may be behavioural characteristics of krill which segregate adult and adolescent concentrations; these would need to be identified by biological sampling in conjunction with the "learning processes" that fishing captains would inevitably go through. It may also be possible to regulate fishing to within areas that do not contribute to maintaining the population (it has been suggested that South Georgia is such an area).

Mention has already been made of the proposed use of remote sensing techniques for estimating the standing stock of krill. The method depends on the identification of swarms of krill either by satellite photography or acoustically and confirming the presence of krill by field sampling. The identification of indications as being krill swarms is a technological problem which can probably be solved. However, some caution should be exercised in the interpretation of the results.

Presently available information indicates that krill swarms are transient phenomena depending for their formation on a variety of external causes one of which is probably food availability. In addition it is not known what proportion of the krill population at any one time is present in swarms.

On the assumption that food availability is a factor leading to swarm formation (the more food, the more swarms) it is arguable that consumption of krill (whether by predation or fishing) would increase the amount of krill in swarms, because the decreased grazing by krill would tend to increase the relative food availability. The effect would be that observations on the abundance or density of krill in swarms would tend to underestimate the change in total krill abundance as the season progressed. In order to overcome this problem it is almost certainly necessary to gain information on the amount of krill not present in swarms in relation to season, the presence of swarms and food and also environmental characteristics.

### 6.10. Harvesting at higher trophic levels

Due to the supposed sensitivity of the Antarctic ecosystem it has been suggested that a safer method of harvesting krill might be by harvesting krill consumers (either natural or introduced) rather than krill. In this context natural consumers are generally considered synonymous with whales although it could equally well apply to seals, fish or squid. From the conservation viewpoint the utilization of krill via the whales has several points in its favour (e.g. exploitation of whales is now under international control, the catch limits are based on scientific information that, if not as reliable as might be wished, is at least much more reliable than that on krill, and the present resolve by conservation pressure groups in particular and scientists in general that overexploitation should not recur) which will buffer it against overexploitation. In the present situation it is more sensible to consider the feasibility from all points of view of exploiting both krill and its consumers and in this context the relative levels of exploitation would be considered in the context of a multispecies fishery (Horwood, 1976).

In a paper discussing the interactions between the North Sea fisheries for dogfish and herring (the herring being an important food organism of the dogfish) Gulland (1970a) derived the general equation below comparing the relative merits in terms of value of harvesting the predator or prey species:

$$\sum_{,}^{n} V' E' K_i wi > \sum_{,}^{n} V_i E_i \overline{w}_i$$

V,V' = Value per unit weight of prey and predators respectively

E,E' = Exploitation rate of prey and predators respectively

k = Conversion ratio prey to predator

$w, \overline{w}$ = Mean weight of individual items eaten and in the catches respectively

The summation is over all prey species.

In the form that the equation is written here the greatest value would result from harvesting the predator.

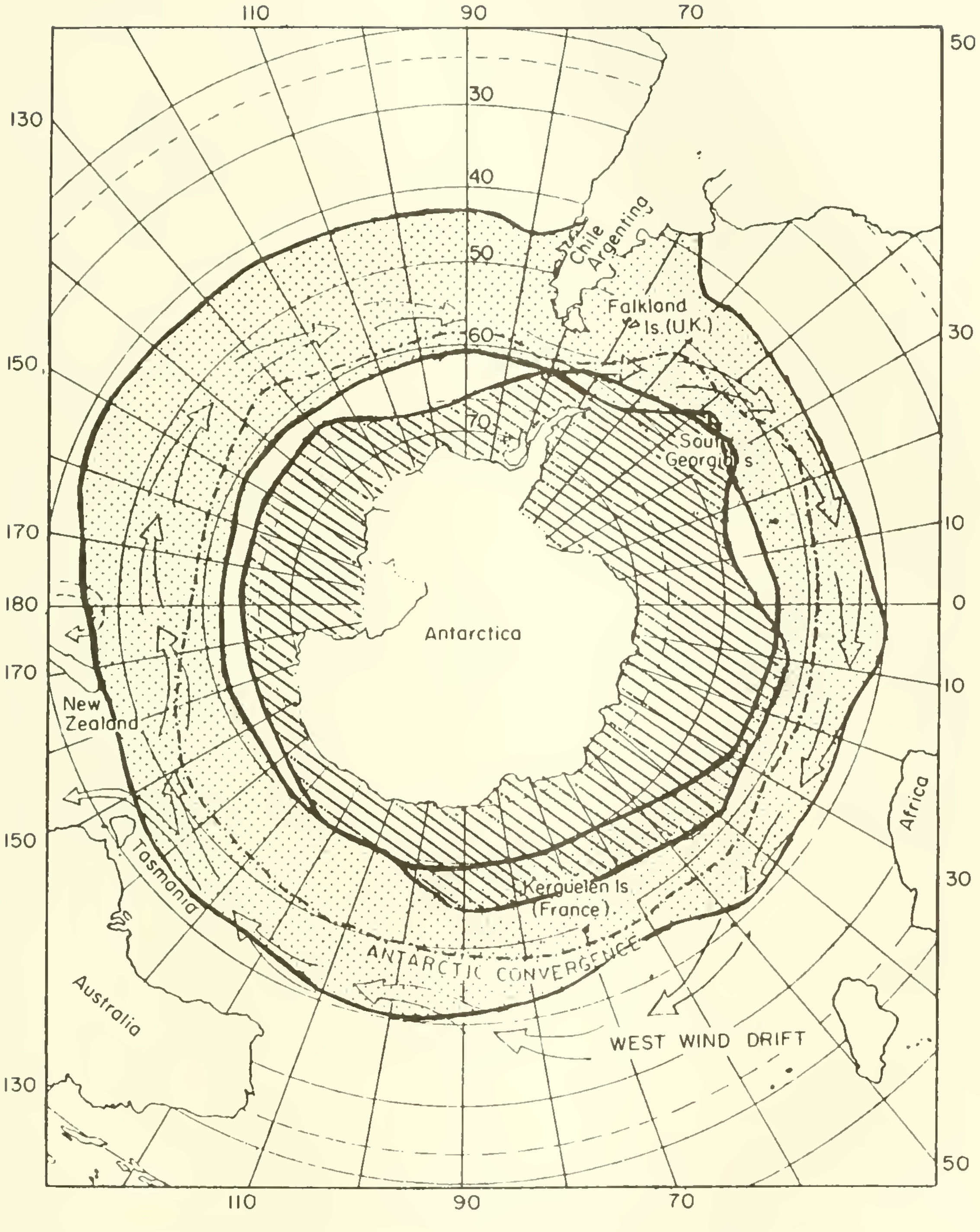
With only slight rearrangement this general equation may be applied to the krill/whales type situation. In this case there is only one prey species but several predators. Using the same notation except that the summation is over the different predator species (whales, seals, etc.) the equation then becomes:

$$\sum_{,}^{n} V'_i E'_i K_i W_i > V E \overline{W}$$

Implicit in this equation is the fact that, as Gulland pointed out, the efficiency of utilization (K) should be greater than the product of the relative value, the relative exploitation and the probable growth of the prey.

In this equation a lot clearly depends on the relation between V' and V and K. Gulland (1974) suggeststhat the overall conversion efficiency of krill to whales is very low and of the order of 2% and suggests that if the problem facing the world were of more food at all costs, and the choice were between 1.7 million tons of whales, and 100 million tons of krill, there would be no doubt that preference would have to be given to harvesting krill. Clearly this represents an extreme case which in reality seems unlikely to occur. Between these two extremes there are an infinite number of potential answers particularly if the other exploitable resources are included into the analysis. The problem then reduces to one of making management decisions to utilize and at the same time safeguard the resources.

An alternative indirect method of harvesting krill has been proposed by Joyner et al. (1974) who suggest that the West Wind Drift is a suitable environment for salmon (see also Hardy 1975, Joyner 1976). On the basis of published information on seasonal sea temperature and the distribution of krill they consider that salmon fry released from Southern South America could search out and feed on krill in the Antarctic. Because of the known fast growth rate of salmon they estimate that a salmon fishery of several million tons could be established in the Tierra del Fuego area. They point out the obvious advantage of such a system that since the salmon will probably return to their area of release the expense involved in fishing will be minimal. However, from the information they give it seems unlikely that the salmon will feed on krill since the main concentrations are south of the area regarded as seasonally acceptable to salmon (Fig. 6.8 which is derived from information in Joyner et al. 1974).



░ Areas of seasonally acceptable temperature to salmon

▨ Summer distribution of krill

Fig.6.8 The northern limit of krill distribution (see Fig.6.1) compared with that of the range of surface temperatures acceptable to salmon (shaded area) (from Joyner et al., 1974)

# APPENDIX G

## The Living Resources of the Southern Ocean: Fish

# THE LIVING RESOURCES OF THE SOUTHERN OCEAN

by

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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## THE SOUTHERN OCEAN FISHERIES SURVEY PROGRAMME

In view of the potential importance of the living resources of the Southern Ocean, the United Nations Development Programme (UNDP) Governing Council approved in January 1976 a preparatory phase of a Southern Ocean Fisheries Survey Programme, to be executed by the Food and Agriculture Organization of the United Nations (FAO). The long-term objective of the Programme is to improve the knowledge of the nature, magnitude and distribution of the living resources of the Southern Ocean (South of latitude 45°S), with a view to assisting in their eventual rational utilization. The immediate activities of the preparatory phase (to continue until the end of 1977) include a review of the present information on the distribution and magnitude of the living resources of the Southern Ocean; a review and evaluation of the present state of exploitation and utilization of these resources; and the establishment of a system for regular compilation of statistical and other information about them.

This report is one of a series prepared by FAO under the preparatory phase of the Programme. It gathers together current knowledge on the magnitude and distribution of the living resources of the Southern Ocean. Other reports in this series assemble current knowledge on the technology of harvesting and on the utilization of krill.

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M-43

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# 8. FISH

## 8.1 Introduction

In most of the world's seas the fish fauna has been a subject of special study because of its economic importance. Although the value of Antarctic fish as food has long been recognised by expeditions of discovery, (one of the first fish specimens caught near to the Antarctic continent was eaten by the ship's cat before it could be properly described, Schlee 1973), it is only recently that commercial fishing has begun. There are in the literature several good reviews which include biological information outside the scope of this report (e.g., Marshall 1964, Andriashev 1965). In addition to these, Kock (1975) has prepared an extensive review which also includes an extensive bibliography, of selected species of potential commercial importance in the Atlantic sector of the Antarctic.

## 8.2 Species

Of the 20 000 kinds of modern fishes only about 100 have been discovered in the seas south of the Antarctic Convergence. Thus, although the Southern Ocean is continuous with the other major oceans of the world, it clearly represents quite a specialised environment. The dominant group in the Antarctic ichthyofauna is the Nototheniiformes, a division comprising five families that make up nearly threequarters of all coast fish species. Of these five families only the Nototheniidae and Channichthyidae contain representatives of potential commercial importance. The remaining groups include the following: Myxinidae, Dalatiidae, Rajidae, Muraenolepidae, Zoarcidae, Congiopodidae, Liparidae, Bothidae, Gadidae, Merlucciidae, of which only the Rajidae and the last two contain species of potential major commercial importance.

In contrast to the other oceans of the world the Southern Ocean does not appear to contain dense shoals of obligate pelagic fish. The pelagic ichthyofauna is largely made up of Myctophidae in addition to the Notothenid genera Pleuragramma and Dissostichus and the Gadoid genus Micromesistius.

The Myctophidae and other bathypelagic groups have not been included in Table 8.1 because present indications suggest that although they may well be abundant in the open ocean they do not form concentrations on which a fishery could be based. The most abundant bathypelagic species of the Antarctic according to Andriashev (1965) are:

Electrona antarctica

Gymnoscopelus braueri

Bathylagus antarcticus

Notolepis coatsi

Cyclothone microdon

A list of the species of potential importance is given in Table 8.1. Taxonomic information will be found in Norman (1937, 1938) along with good identification keys.

## 8.3 Distribution

As is the case with many areas that are unfished commercially, knowledge of the distribution of many species is incomplete. The information given in the maps (Fig. 8.1 a - k) will in only few cases indicate the area of abundant distribution. The information from the maps should be used in conjunction with the bathymetric information given in Table 8.2 along with a detailed contour chart in order to gain the best idea of the distribution. Pleuragramma antarcticum has been excluded from the distribution maps. This species is considered to have a high latitude circumpolar distribution, it has not been recorded in the vicinity of the Antarctic Convergence. The bathypelagic fish species have also been excluded and they are assumed to have a circumpolar distribution over more or less the whole Southern Ocean.

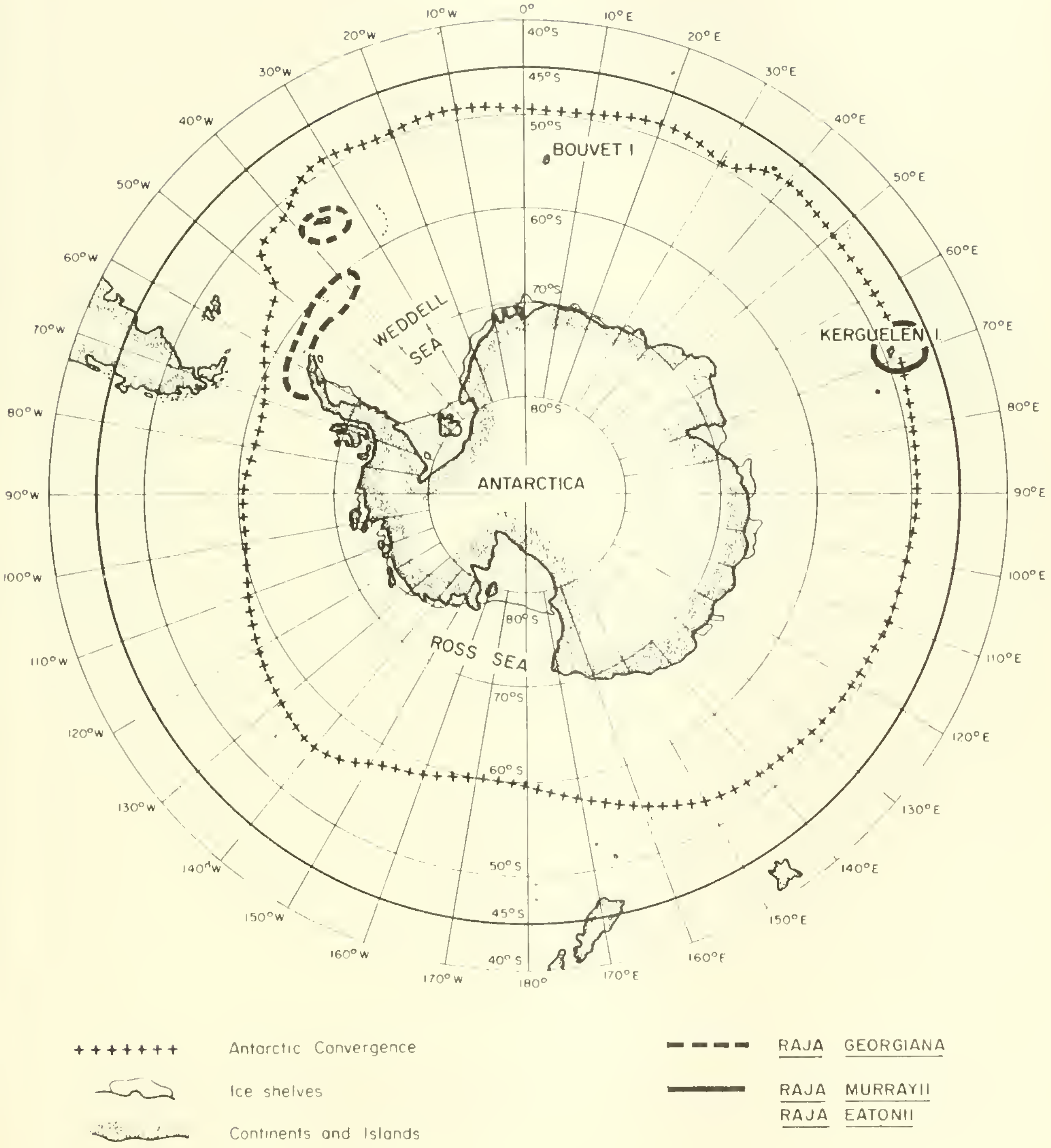

Fig.8.1 (a) Distribution of main fish species in the Southern Ocean

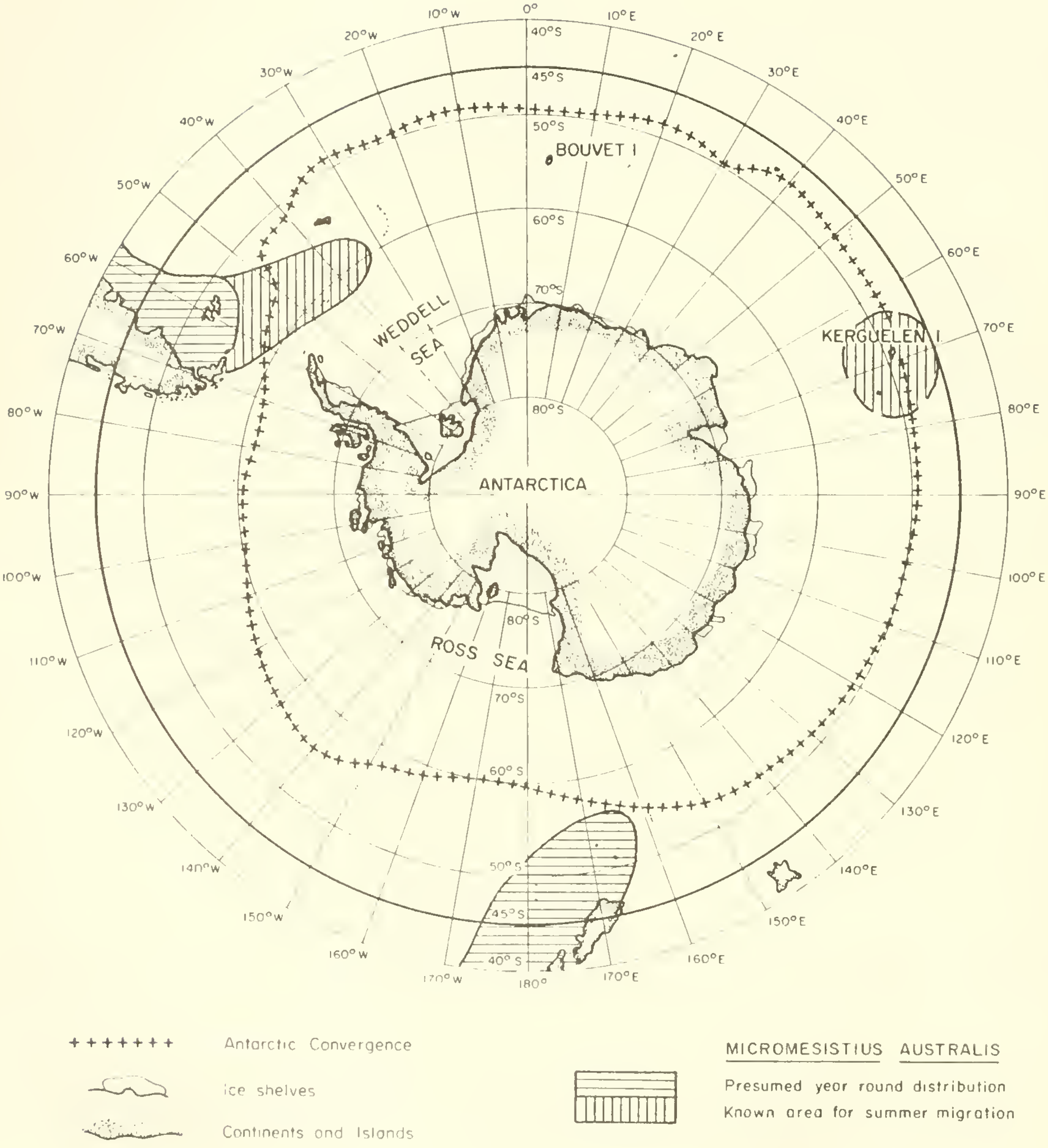

Fig.8.1 (b) Distribution of main fish species in the Southern Ocean

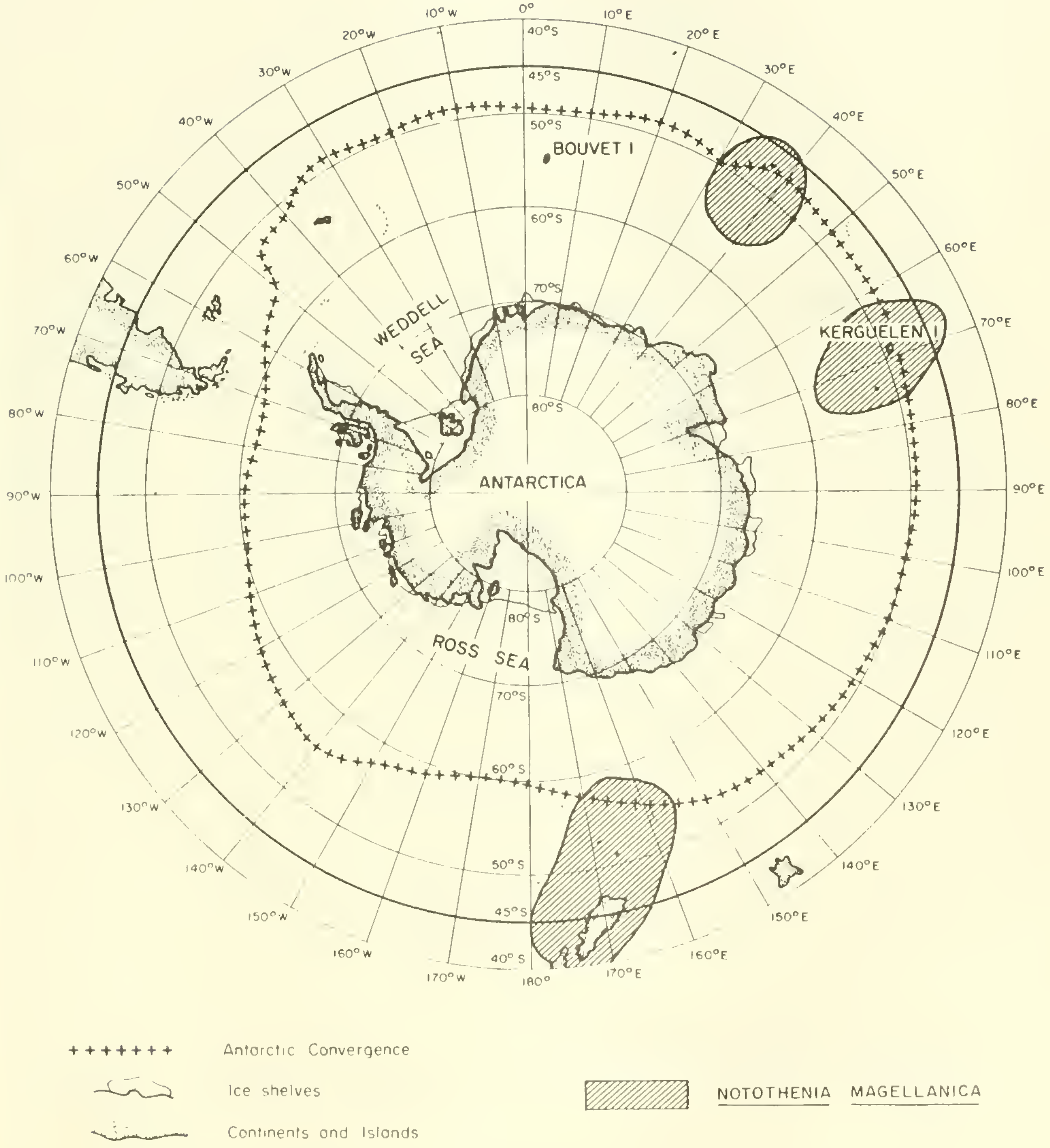

Fig.8.1(c) Distribution of main fish species in the Southern Ocean

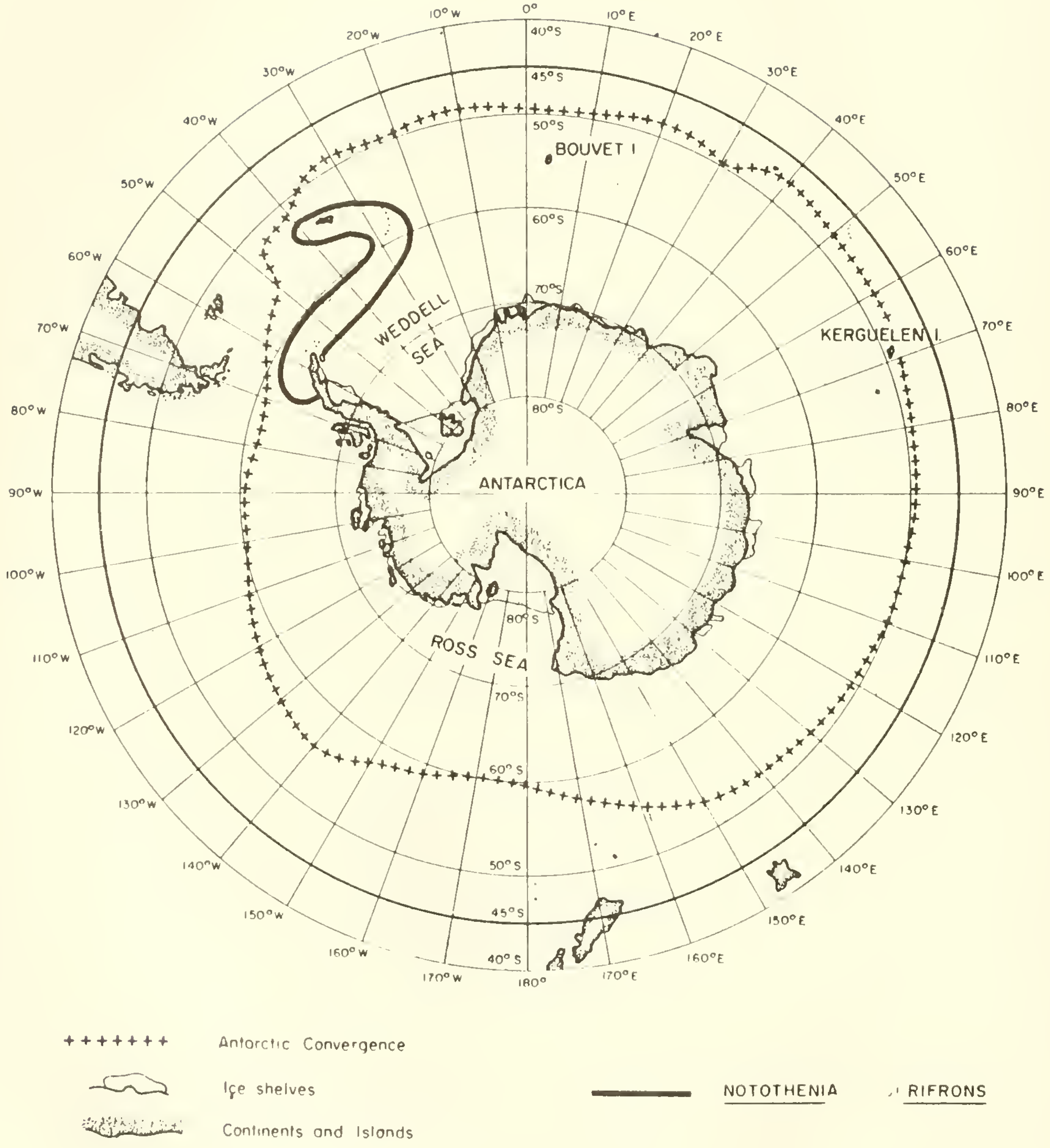

Fig.8.1 (d) Distribution of main fish species in the Southern Ocean

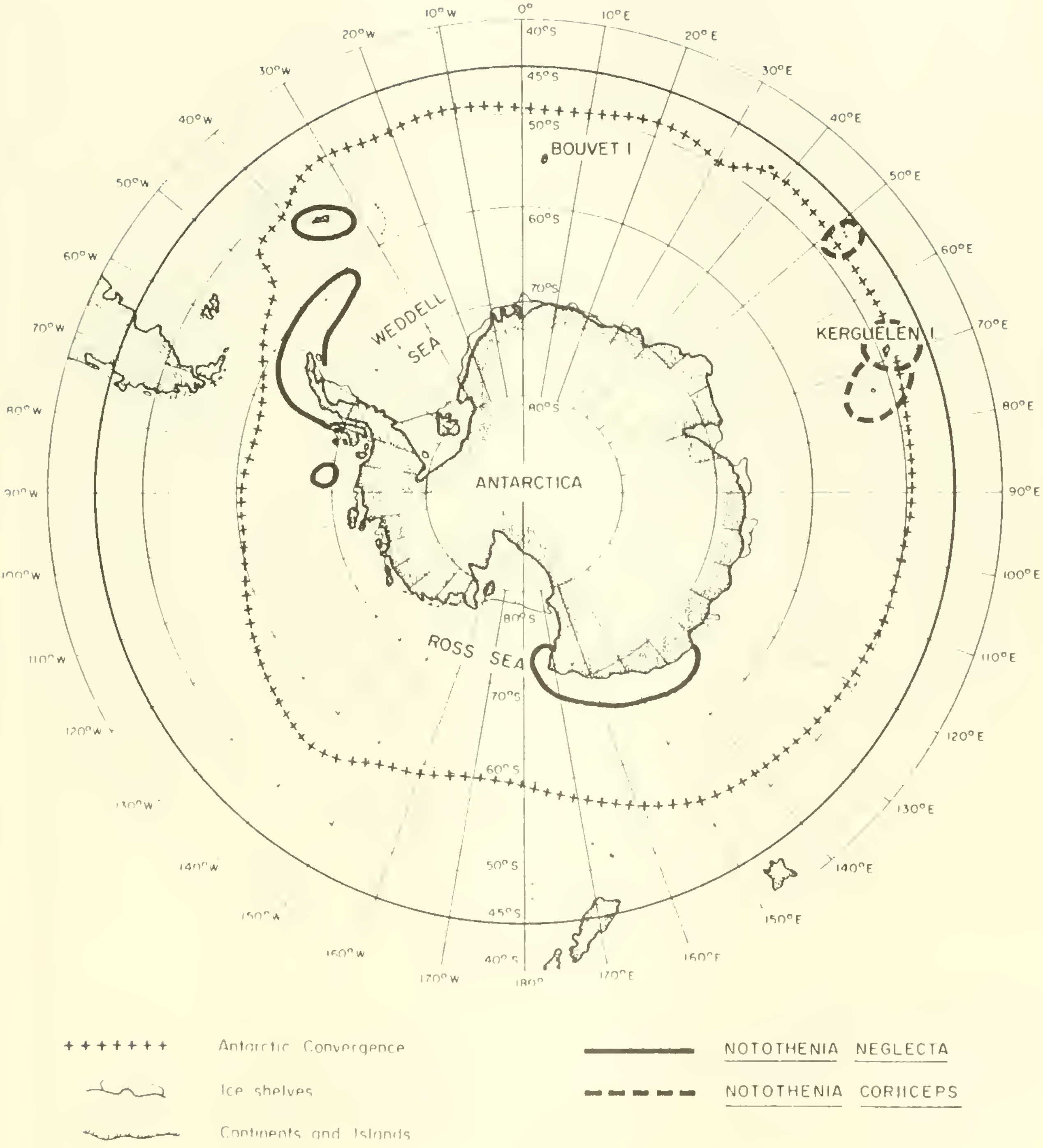

Fig.8.1 (e) Distribution of main fish species in the Southern Ocean

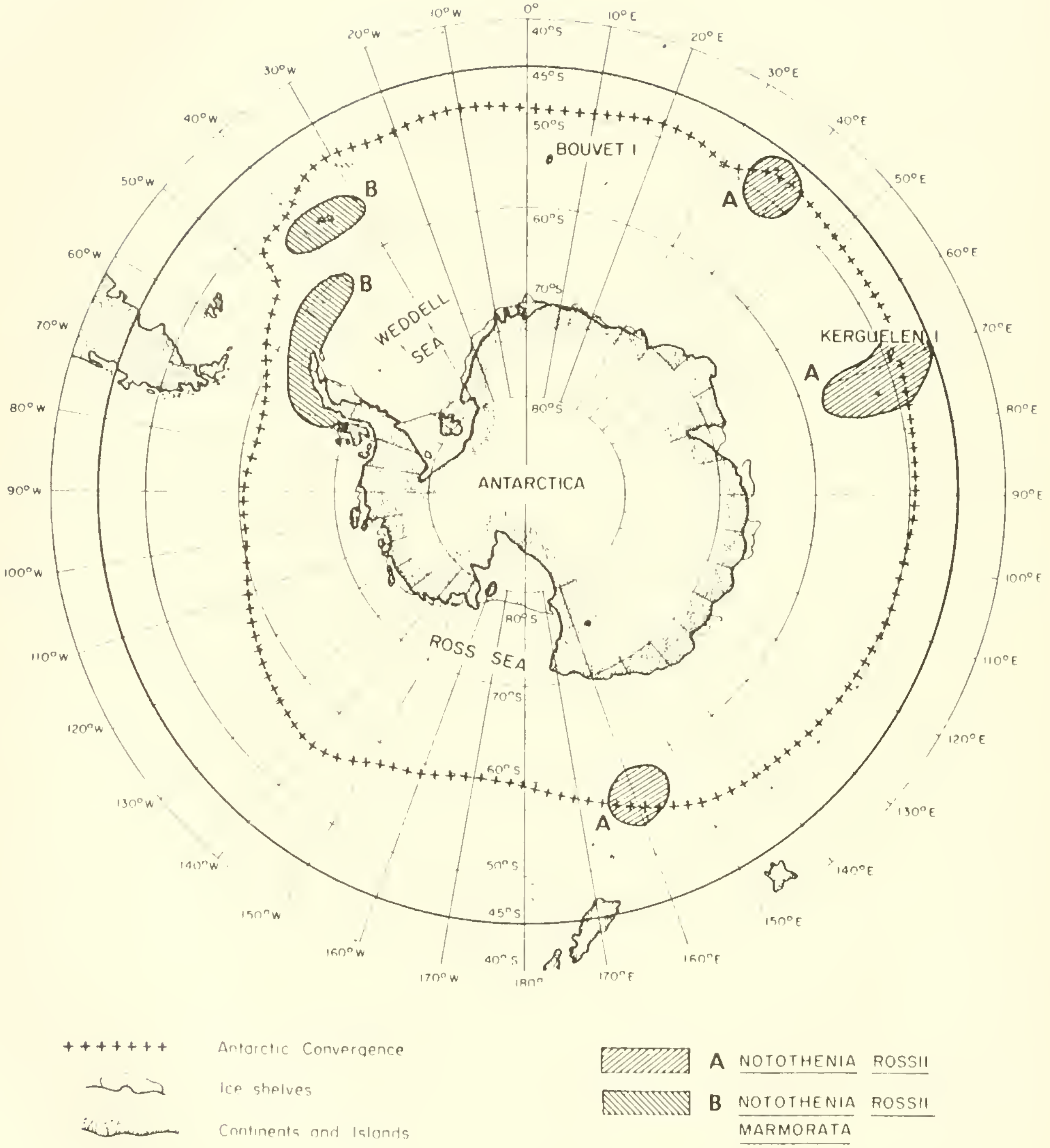

Fig.8.1 (f) Distribution of main fish species in the Southern Ocean

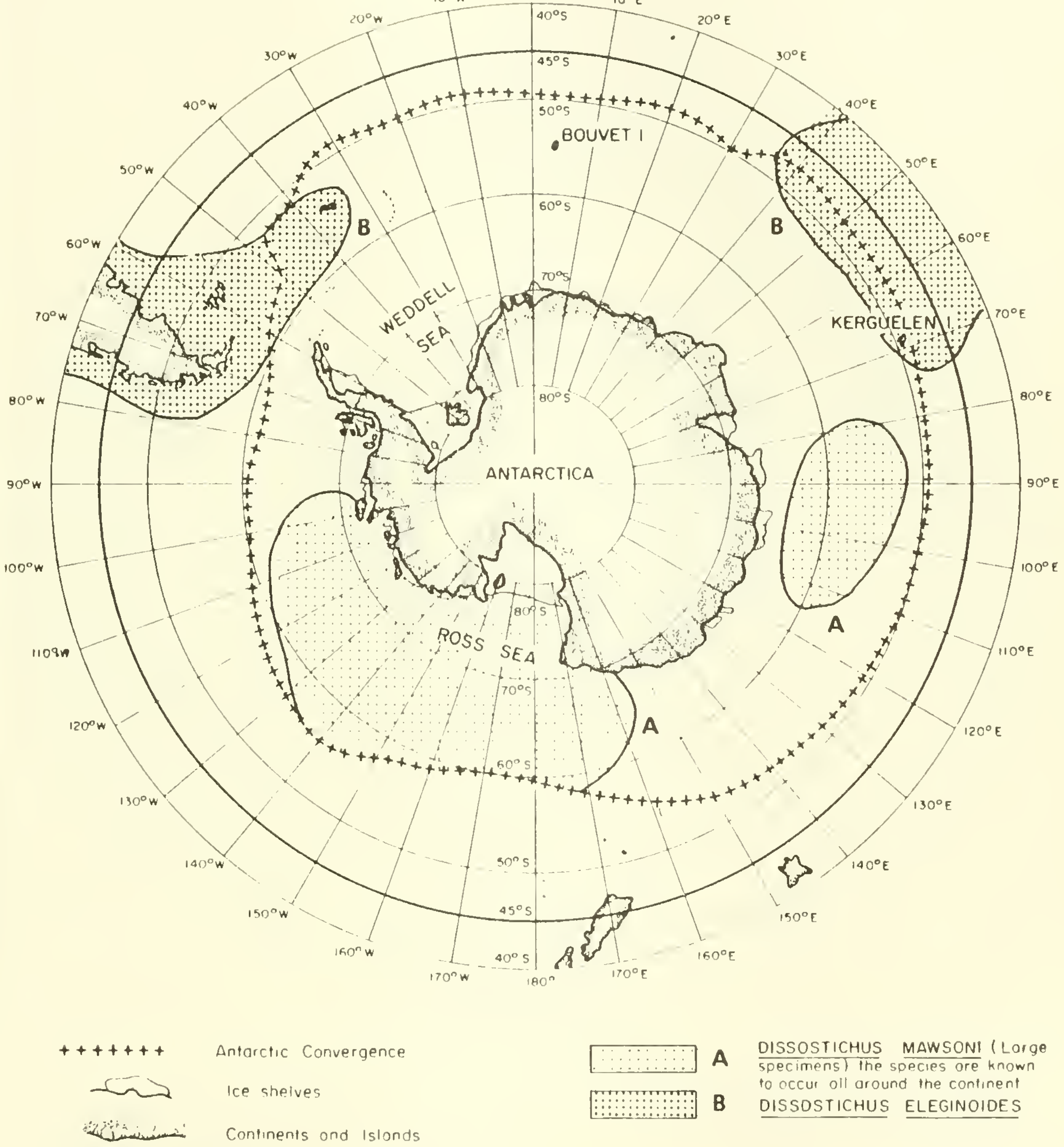

Fig.8.1 (g) Distribution of main fish species in the Southern Ocean

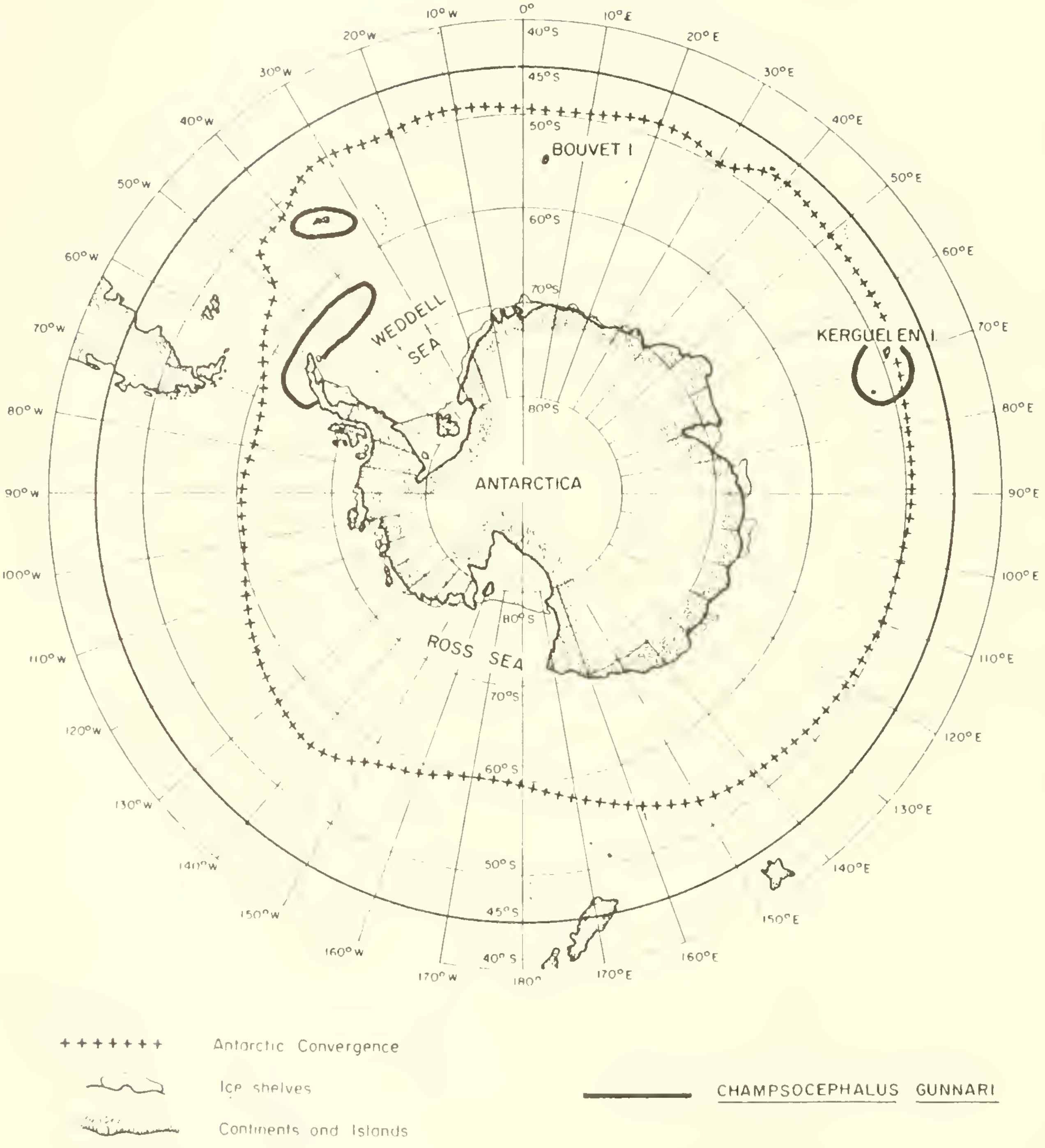

Fig.8.1 (h) Distribution of main fish species in the Southern Ocean

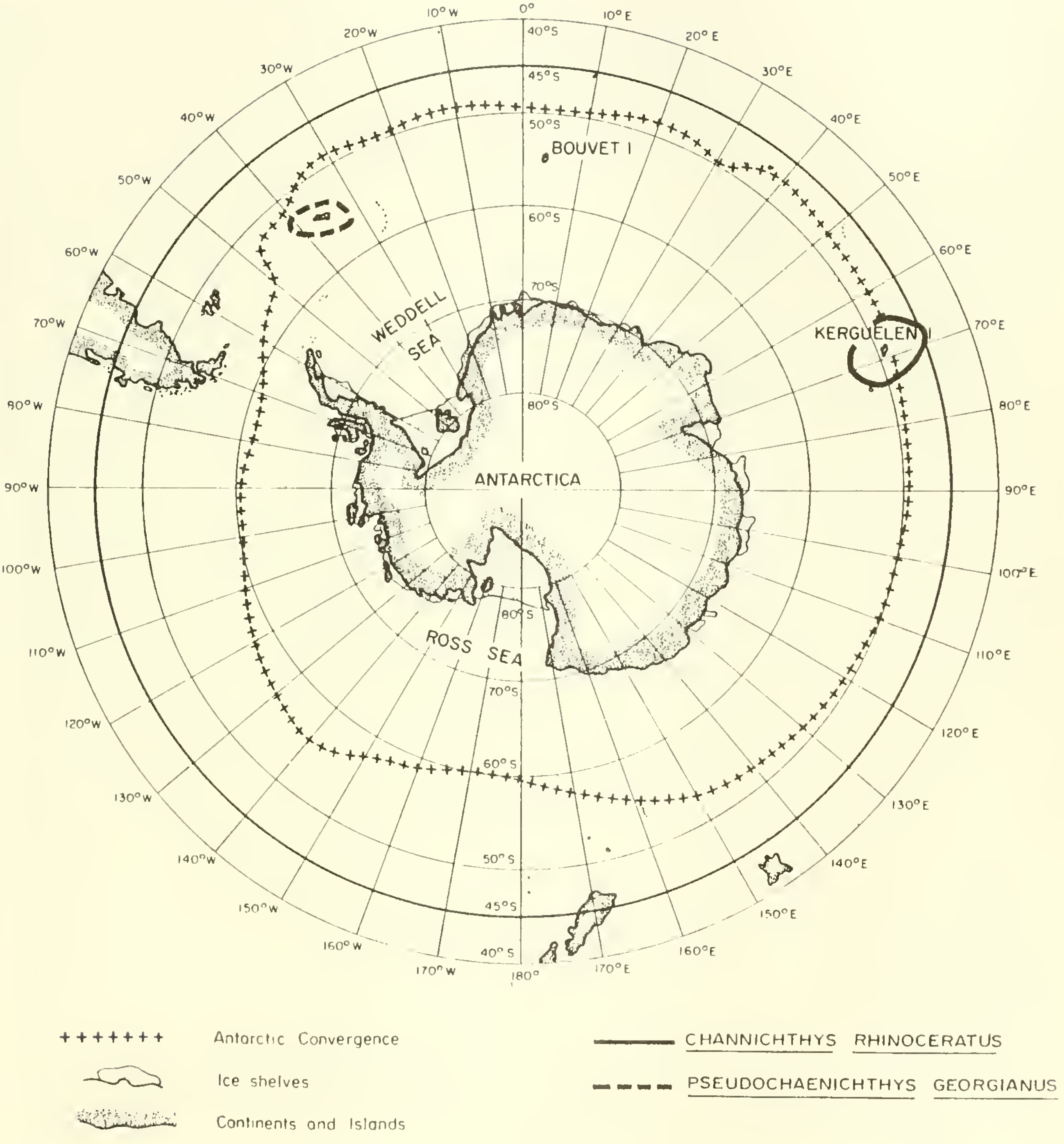

Fig.8.1 (i) Distribution of main fish species in the Southern Ocean

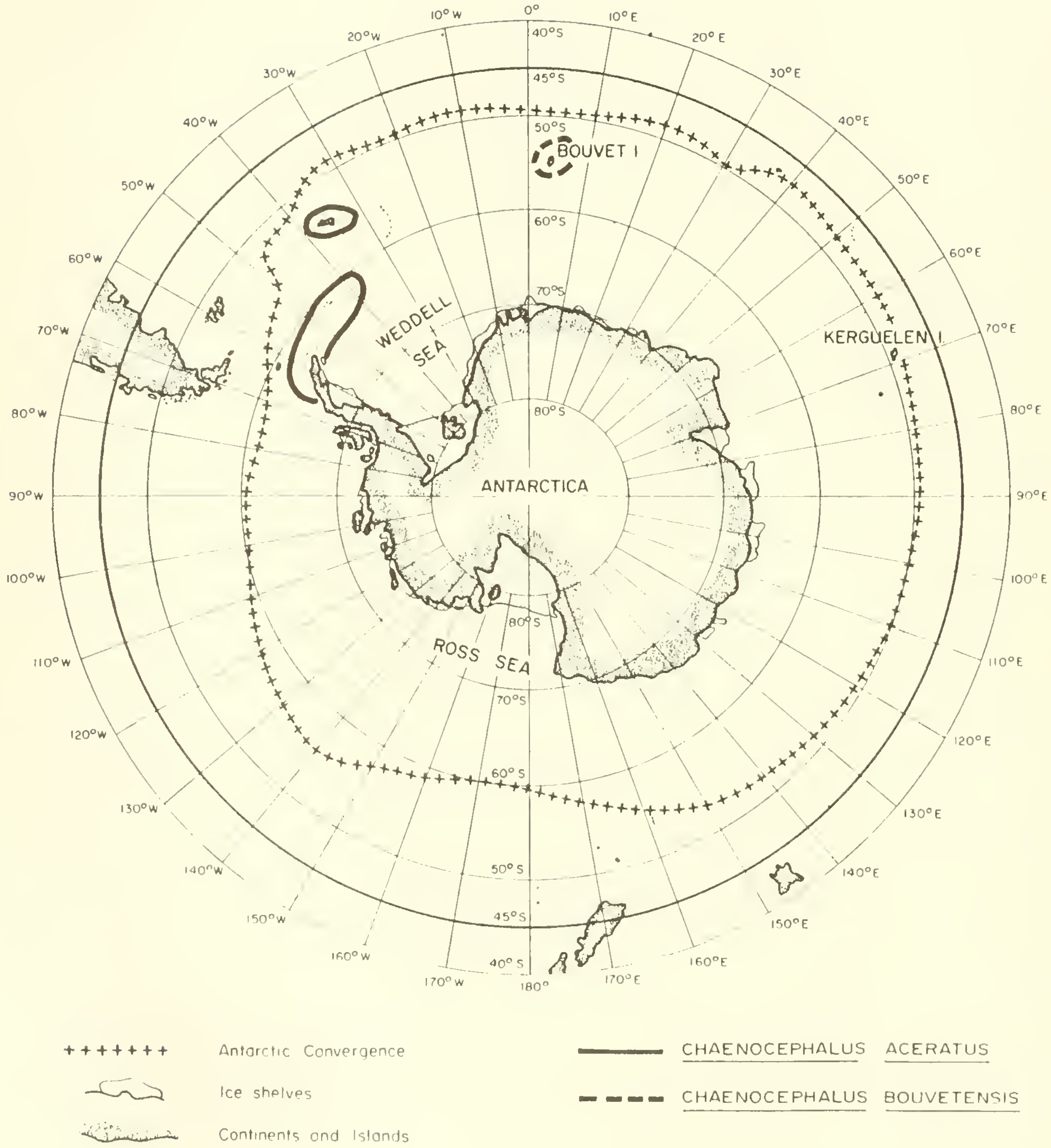

Fig.8.1 (j) Distribution of main fish species in the Southern Ocean

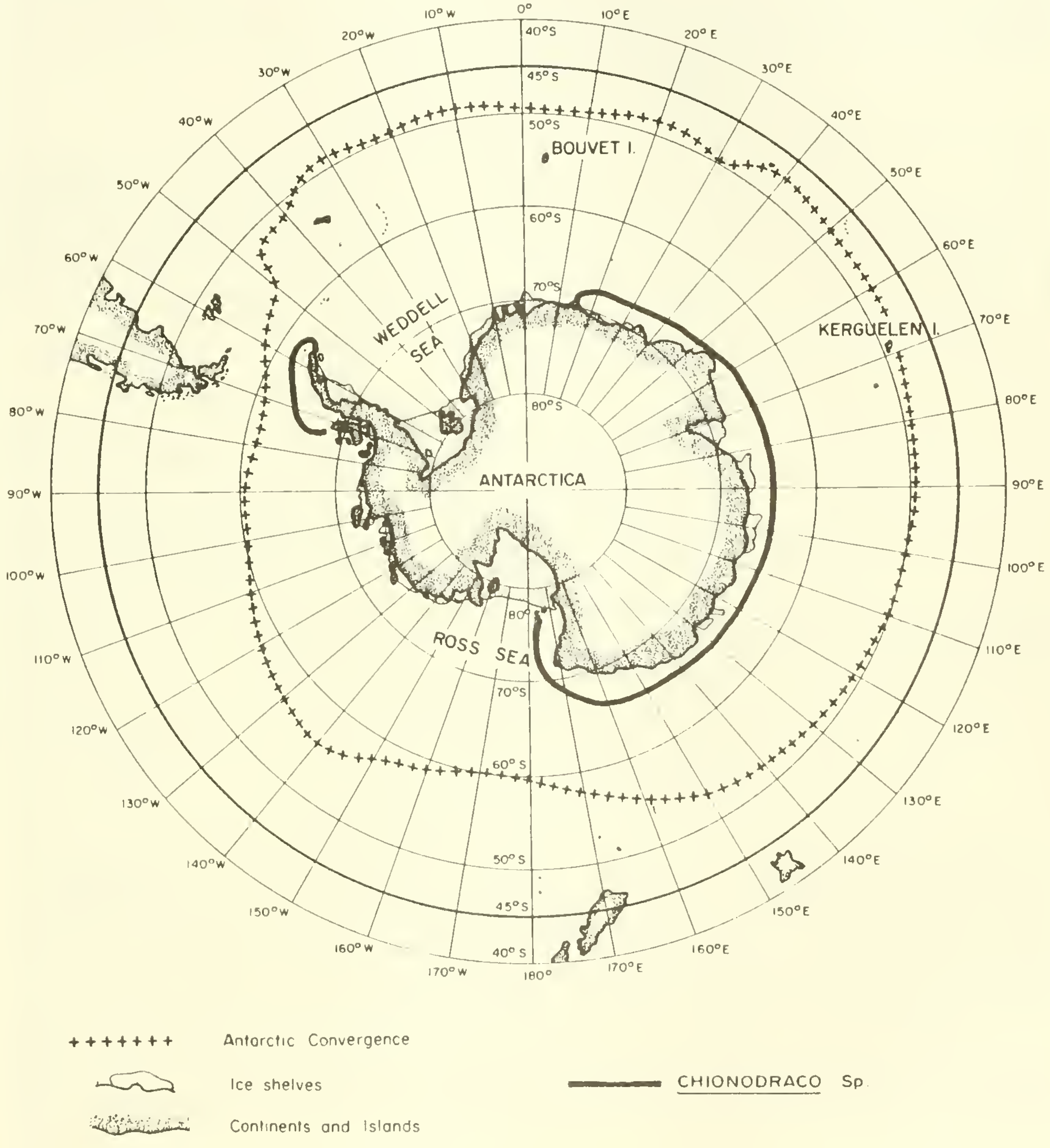

Fig.8.1 (k) Distribution of main fish species in the Southern Ocean

Table 8.1. Fish species of potential commercial importance in the Southern Ocean

| Group | Species | Common Name |
|---|---|---|
| Rajidae | Raja georgiana<br>R. murrayi<br>R. eatonii | |
| Gadidae | Micromesistius australis | Southern Blue Whiting or Southern Poutassou |
| Merluciidae | Merluccius hubbsii | Patagonian Hake |
| Nototheniidae | Notothenia gibberifrons | |
| | N. coriiceps | |
| | N. neglecta | |
| | N. rossii rossii | |
| | N. rossii marmorata | Marbled Notothenia |
| | N. magellanica | |
| | Dissotichus mawsoni | Antarctic Tooth Fish |
| | D. eleginoides | Patagonian Tooth Fish |
| | Pleuragramma antarcticum | |
| Channichthyidae | Champsocephalus gunnari<br>Channichthys rhinoceratus<br>Pseudochaenichthys georgianus<br>Chaenocephalus sp.<br>Chionodraco sp. | |

Although there are several species of hake in the Southern Hemisphere, Merluccius hubbsii is the only species to have been reported from Antarctic waters (Mikheyev 1967). In this single instance fish were assumed to have migrated into the Antarctic to feed on krill. This migration is not consistent with the shoreward summer migration pattern in Patagonia described by Hart (1946), a movement confirmed by the observations of Ciechomski and Weiss (1974) who found that M. hubbsii spawned in shallow water during the summer.

The restriction of the distribution of many species to the continental shelf zone has probably resulted in the establishment of distinct stocks (even if not genetically at least as far as fishery management is concerned). Species where this is thought to be the case along with the defined localities are listed in Table 8.3.

Table 8.2. Distribution of Antarctic Fish
(See also Fig 8.1 *a - k*)

| Species | Habitat and Mode of Life | Depth Range | Reference |
|---|---|---|---|
| *Raja georgiana* | Demersal, South Georgia Shelf also from a submerged elevation between S. Orkney and S. Sandwich Island (-1.44 to -1.47°C) | 180-830 | 1, 2, 3 |
| *R. murrayii* | Demersal, Kerguelen | 20-60 | 1 |
| *R. eatonii* | Demersal, Kerguelen | 30 | 1 |
| *Micromesistius australis* | In the Antarctic. Reports indicate this species is *generally* pelagic in the vicinity of the continental shelf.<br>Has been caught in bottom trawls although larger catches have been made with pelagic trawls. | 200-650<br>10-70 | 2, 4, 5, 6 |
| *Merluccius hubbsii* | Reported on only one occasion Pelagic, assumed migrated to Scotia Sea from Patagonia | | 7 |
| *Notothenia gibberifrons* | Demersal in shelf area of Scotia Arc | 5-350 | 1 |
| *N. coriiceps* | Demersal, Shelf area Kerguelen, Crozet | 0-200 | 1 |
| *N. neglecta* | Demersal in Shelf area of Scotia Arc and around continent | 0-200 | 1 |
| *N. rossii rossii* and ) | Juveniles demersal in shallow water | 0-30 | 8, 9 |
| *N. rossii marmorata* ) | Adults demersal/pelagic in shelf area | 0-400 | |
| *N. magellanica* | Originally considered coastal species living on kelp, now known to be pelagic krill feeder | 0-80 | 1 |
| *Dissostichus mawsoni* | Mainly pelagic in open ocean | 20-220 | 10 |
| *D. eleginoides* | Mainly pelagic | 70-800 | 10 |
| *Pleuragramma antarcticum* | Open ocean pelagic although often associated with Continental Shelf | | 11, 1, 14 |
| *Champsocephalus gunnari* | Pelagic/demersal in Shelf area | 0-450 | 12, 1 |
| *Channichthys rhinoceratus* | Demersal | 0-140 | 13, 1 |
| *Pseudochaenichthys georgianus* | Demersal/pelagic in Shelf area | 0-270 | 12 |
| *Chaenocephalus* sp. | Demersal | 5-350 | 12, 1 |
| *Chionodraco* sp. | Demersal | 0-800 | 1 |

References for Table 8.2.

| | | |
|---|---|---|
| 1. | DeWitt | 1971 |
| 2. | Permitin | 1969 |
| 3. | Bigelow and Schroeder | 1965 |
| 4. | Merrett | 1963 |
| 5. | Basalaev and Petukhov | 1969 |
| 6. | Shuntov | 1971 |
| 7. | Mikheyev | 1967 |
| 8. | Olsen | 1954 |
| 9. | Hureau | 1970 |
| 10. | Yukhov | 1970, 1971 (s), 1972 |
| 11. | DeWitt and Hopkins | (in Press) |
| 12. | Olsen | 1955 |
| 13. | Hureau | 1966 |
| 14. | Lyubimova *et al.* | 1973 |

Table 8.3. Antarctic Fish Species for which there is positive evidence for more than one discrete management stock.

| Species | Stock Localities | Reference |
|---|---|---|
| *Micromesistius australis* | (a) Scotia Sea, probably Southern limit of Patagonian population. | |
| | (b) Campbell Plateau | |
| | (a) and (b) Related subspecies on morphological grounds | Inada and Nakamura 1975 |
| | (a) and (b) Not considered of subspecific status but considered isolated | Shpak 1975 |
| | This species has also been reported from S. W. Indian Ocean | FAO |
| *Notothenia rossii* | (a) Kerguelen Crozet group considered of subspecific status *N. rossii rossii*, Richardson | Nybelin 1947 |
| | (b) Scotia Arc. considered of subspecific status *N. rossii marmorata*, Fischer | Nybelin 1947 |

## 8.4 Size and Growth

In the Antarctic ichthyofauna small species are dominant, over half the species do not attain a length of 25 cm and few species attain a length of over half a metre (Andriashev 1965). It is an interesting point that most of the larger species belong to the family Channichthyidae, a group possessing neither functional erythrocytes nor any respiratory pigment. Growth rates are, with few exceptions, slow as might be expected in an environment of continually low temperatures. The limited information that is available is set out below.

### *Raja* sp.

The South Georgia skate, *Raja georgianus* is one of the largest Antarctic fishes. Permitin (1969) gives the size/weight composition for 31 fish from a large sample caught in the vicinity of South Georgia (Table 8.4). No information is available on growth rate.

Table 8.4. Length/Weight information for *Raja georgianus*.

| Total Length (cm) | Wt.(g) | No. |
|---|---|---|
| 20 - 30 | 146 | 3 |
| 30 - 40 | - | - |
| 40 - 50 | 860 | 1 |
| 50 - 60 | 1 780 | 3 |
| 60 - 70 | 2 680 | 11 |
| 70 - 80 | 3 800 | 2 |
| 80 - 90 | 6 015 | 4 |
| 90 - 100 | 7 690 | 4 |
| 100 - 110 | 10 850 | 2 |
| 110 - 120 | 13 700 | 1 |

### *Micromesistius australis*

Information on growth is only available for this species from Patagonia and the Scotia Sea areas (Table 8.5.).

Table 8.5. Length (cm) against Age results for *Micromesistius australis*

| Locality | AGE GROUP | | | | | | | | | | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII | VIII | IX | X | |
| S.Orkney Is. ♂ | | | 40 | | 45/46 | 48/49 | | | | | Mikheyev 1967 |
| ♀ | | | | 45/47 | 48/49 | | | | | | |
| S.Orkney Is. ♂ | | | | 45 | 47 | 48 | 50 | 50 | 51 | 53 | Shubnikov, *et al.* 1969 |
| ♀ | | | 46 | 48 | 49 | 49 | 50 | 52 | 53 | 65 | |
| Patagonia ♂ | | | 44 | 45 | 46 | 47 | 49 | 50 | - | 55 | Shubnikov, *et al.* 1969 |
| ♀ | | | 44 | 46 | 47 | 48 | 49 | 51 | 52 | 58 | |
| Patagonia ♂ | 13 | 21 | 29 | 37 | | | | | | | Inada and Nakamura 1975 |
| New Zealand ♂ | 13 | 22 | 29 | | | | | | | 47 | Inada and Nakamura 1975 |

The results of Inada and Nakamura (1975) refer to fork length and the remainder (although this is not stated) probably refer to total length. The difference in size at age between results of Inada and Nakamura and those of the Russian workers is almost certainly due to gear selectivity although the possibility of its being due to interpretation of the otolith rings cannot be ruled out.

Merluccius hubbsii

Information relating size to age for this species was published by Mikheyev (1967) and is summarised in Table 8.6.

Table 8.6. Size at age information for Merluccius hubbsii in the Scotia Sea

| Length (cm) | Weight (g) | Age (yr) |
|---|---|---|
| 34 - 35 | 260 | (?) |
| 21 - 27 | - | - |
| 28 - 35 | - | 2 |
| 34 - 35 | - | 2 |

Notothenia neglecta

Results from two localities, Terre Adelie (Hureau 1970) and Signy Island, South Orkneys (Everson 1970) are set out in Table 8.7.

Table 8.7. Size at age information for Notothina neglecta

| Age Group | Length (cm) | | | | Weight (g) | | | |
|---|---|---|---|---|---|---|---|---|
| | TA ♀ | Signy | TA ♂ | Signy | TA ♀ | Signy | TA ♂ | Signy |
| V | | 22.0 | 16.5(6) | 22.5 | | 311 | 107 | 318 |
| VI | 18.2(22) | 24.0 | 18.5(7) | 24.6 | 141 | 401 | 147 | 415 |
| VII | 21.4(22) | 25.9 | 20.4(20) | 26.4 | 225 | 502 | 190 | 513 |
| VIII | 24.6(10) | 27.5 | 22.3(18) | 28.0 | 338 | 607 | 240 | 612 |
| IX | 27.8(8) | 29.0 | 24.2(9) | 29.4 | 480 | 716 | 316 | 705 |
| X | 31.0(6) | 30.5 | 26.2(5) | 30.4 | 670 | 827 | 387 | 794 |
| XI | 34.2* | 31.8 | 28.1(7) | 31.6 | 890 | 939 | 500 | 879 |
| XII | 37.4* | 33.0 | 30.0(2) | 32.5 | 1 157 | 1 048 | 620 | 960 |
| XIII | 40.6(1) | 34.1 | 31.9* | 33.4 | 1 485 | 1 150 | 760 | 1 034 |
| XIV | | 35.0 | | 34.1 | | 1 245 | | 1 101 |
| XV | | 35.8 | | 34.7 | | 1 337 | | 1 161 |

( ) = Figures in parentheses are sample size.
* = Calculated value (The data from Signy Island are calculated values based on examination of 2 000 otoliths)

Hureau (1970) tried to fit a Bertallanfy curve to his results from Terre Adelie but could not obtain a realistic estimate for $L_\infty$. He therefore derived the following alternative equations.

$$L_t = 3.2\ (t) - 1.0 \qquad (\text{♀}\ t > 6)$$
$$L_t = 1.925\ (t) + 6.9 \qquad (\text{♂}\ t > 5)$$

A Bertallanfy curve was fitted to the results from the Signy Island fish and the constants are set out in Table 8.8.

Table 8.8. Constants for the Bertallanfy curve derived for N. neglecta at Signy Island

| | K | $L_\infty$ | $W_\infty$ | $t_0$ |
|---|---|---|---|---|
| ♀ | 0.091 | 45.5 | 2 744 | -1.7 |
| ♂ | 0.129 | 39.5 | 1 728 | -0.8 |

## Notothenia rossii

Size at age has been studied at Kerguelen (Hureau 1970) and also at South Georgia (Olsen 1954, Crisp and Carrick 1975). These results are summarised in Tables 8.9 and 8.10.

Table 8.9. Notothenia rossii rossii from Kerguelen (Hureau 1970).

| | AGE GROUP | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII | VIII | IX | X |
| Mean Standard Length ♀ | 11.2<br>(12) | 17.1<br>(17) | 23.5<br>(62) | 32.1<br>(23) | 39.3<br>(9) | 50.0<br>(1) | 55.0<br>(2) | 60.0<br>(2) | 64.0* | 67.0* |
| ♂ | | | | | | 48.0<br>(3) | 53.0<br>(2) | 57.0* | 61.0<br>(1) | 63.0* |
| Mean Weight (g) | 41 | 131 | 293 | 752 | 1200 | 1963 | 2800 | 3815 | | |

( ) = Figures in parentheses are sample size.
* = Estimated value

Table 8.10. Constants of the Bertallanfy curve for N. rossii rossii from Kerguelen.

| | K | $L_\infty$ | $t_o$ |
|---|---|---|---|
| ♂ | 0.13 | 80 | -1.69 |
| ♀ | 0.13 | 90 | -0.62 |

Table 8.11. Size at age information for Notothenia rossii marmorata from South Georgia (Olsen 1954)

| | Age Group | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII | XIII | XIV |
| Length (cm) ♀ | 7 | - | 22 | 28 | 32 | 44 | 51 | 59 | 61 | 64 | 67 | 70 | 72 | 72 |
| ♂ | | | | | | | 50 | 57 | 59 | 62 | 64 | 65 | 68 | 69 |

Bertallanfy curves were fitted to the data for South Georgia with the constants that are set out in Table 8.12 (Everson 1970).

Table 8.12. Constants of the Bertallanfy curve applied to data of Olsen (1954) for Notothenia rossii from South Georgia.

| Age Group | K | $L_\infty$ | $t_o$ |
|---|---|---|---|
| I - V | 0.15 | 75 | 0.1 |
| V - XIV | 0.29 | 75 | 3 |

The change in the growth pattern had previously been described by Olsen (1954) as being coincident to, and therefore probably a result of, the offshore migration of the fish.

The age determination methods employed by Olsen and Hureau in their studies were based mainly on otolith examination although they both examined scales as a check. Crisp and Carrick (1975), from examination of the scales from fish of known size caught at Leith Harbour, South Georgia, were able to corroborate Olsen's size at age estimates both by direct comparison and by back calculation based on the ratio of scale length to total length corrected for allometry. Their results confirm the growth pattern described by Olsen for the first few years and also indicate that this technique is of great use in obtaining the maximum amount of information from small samples.

Notothenia magellanica

The only published information on growth of this species is from fish caught at Kerguelen (Hureau 1970). The relevant information is given in Table 8.13.

Table 8.13. Size at age information for Notothenia magellanica at Kerguelen.

| | Age Group | | | | | | |
|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII |
| Length (cm) | 12.1 | 18.0 | 23.4 | 26.6 | 30.3 | 33.1 | 36.5 |
| Weight (g) | 55 | 178 | 374 | 565 | 642 | 886 | 1 176 |
| N | 4 | 18 | 23 | 11 | 11 | 5 | 5 |

Hureau has fitted a Bertallanfy growth curve with the following constants to these results:

$$K = 0.26;$$

$$L\ \infty = 40\text{cm};$$

$$t_o = 0.4\text{yr}.$$

Dissostichus mawsoni and Dissostichus eleginoides

Yukhov (1971a) has described a series of specimens obtained from sperm whale stomachs the sizes of which are set out in Table 8.14.

Table 8.14. Length/Weight information for Dissostichus mawsoni (Data from Yukhov 1971a)

| Length (cm) | Weight ♀ (kg) | Weight ♂ (kg) |
|---|---|---|
| 121-130 | | 24.6 |
| 131-140 | 29.5 | 29.8 |
| 141-150 | 38.9 | 37.2 |
| 151-160 | 53.0 | 49.0 |
| 161-170 | 55.0 | |
| 171-180 | 70.0 | |

In addition Calhaem and Christoffel (1969) give the following information:

| Species | Length (cm) | Weight (kg) | Notes |
|---|---|---|---|
| Dissostichus mawsoni | 147 | 30 | Sp. in Dominion Museum, Wellington, New Zealand |
| | 125 | (18) | Taken from seal |

There is no information available on age determination or size at age for either species although Yukhov (1971b) has described the otoliths in detail for taxonomic purposes.

Pleuragramma antarcticum

No information on growth is available for this species. They are reported to grow to 30-35 cm total length (300 g) (Lyubimova et al., 1973)

Champsocephalus gunnari

Olsen (1955) published information on the size at age for this species at South Georgia and this is summarised in Table 8.15.

Table 8.15. Length at age information for Champsocephalus gunnari data from Olsen (1955).

| | | Age Group | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | III | IV | V | VI | VII | VIII | IX | X | XI | XII |
| Mean Length (cm) | ♂ | 26.8 | 32.5 | 34.9 | 36.3 | 36.7 | 38.2 | 41 | — | 41 | 42 |
| | N | 18 | 11 | 24 | 13 | 10 | 5 | 1 | 0 | 1 | 2 |
| | ♀ | 26.6 | 32.1 | 34.2 | 36.5 | 37.6 | 39.5 | 40.5 | 40 | 41 | — |
| | N | 29 | 24 | 21 | 10 | 9 | 4 | 2 | 1 | 3 | 0 |

Channichthys rhinoceratus

Hureau (1966) has published information on size at age for this species and this is summarised in Table 8.16.

Table.8.16. Size at age information for Channichthys rhinoceratus

| | Age Group | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | II | III | IV | V | IV | VII | VIII | IX | X | XI | XII |
| Mean Length (cm) | 14.8 | 22.3 | 26.0 | 34.0 | 37.0 | 39.7 | 41.0 | 42.5 | — | — | 47.5 |
| Mean Weight (g) | 35 | 150 | 220 | 435 | 510 | 550 | 635 | 750 | — | — | 1 330 |
| N | 2 | 2 | 6 | 7 | 8 | 4 | 3 | 1 | 0 | 0 | 1 |

Pseudochaenichthys georgianus

Detailed information of age and size for this species is lacking although Olsen (1955) gives the following information based on examination of the vertebrae of formalin fixed specimens.

| | |
|---|---|
| First year | 6 – 10 cm |
| Second year | 17 – 23 cm |
| 2 – 3 years old | 27 – 33 |

A single individual (♀) of 50 cm was aged 8 – 9 years.

### *Chaenocephalus aceratus*

The results of Olsen (1955) for this species at South Georgia are summarised in Table 8.17.

Table 8.17. Information on length at age for *Chaenocephalus aceratus*

| | | Age Group | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | IX | X | XI | XII | XIII | XIV | XV | XVI | XVII | |
| Mean Length (cm) | ♂ | 55 | 52 | 51 | 51 | 52 | 52 | 50 | — | — | |
| | N | 1 | 5 | 6 | 3 | 3 | 2 | 1 | 0 | 0 | 21 |
| | ♀ | 62 | 63 | 57 | — | 59 | 65 | — | 62 | 65 | |
| | N | 1 | 3 | 1 | 0 | 3 | 2 | 0 | 1 | 2 | 13 |

Several workers have published equations relating length to total weight for Antarctic fish (Table 8.18). Unfortunately a simple standard equation does not seem to be applicable although all are variations on the simple cubic relationship intuitively expected.

Table 8.18. Length/Weight relationships for Antarctic fish

| Species | Relationship | Locality | Reference |
|---|---|---|---|
| *Raja georgianus* | $W = (0.21L)^3$ | South Georgia | Calculated from results of Permitin (1969) |
| *Micromesisticus australis* | $W = (0.21L - 1.3)^3$<br>see Footnote (1) | Scotia Sea | Estimated from results of Shubnikov (1969) |
| *Notothenia neglecta* | $W = 0.029(L^*)^3$ ♀ | Signy Island | Everson 1970 |
| | $W = 0.028(L^*)^3$ ♂ | Signy Island | |
| | $\log W = 2.92 \log L^* - 4.45$ | Terre Adelie | Hureau 1970 |
| *N. rossii rossii* | $\log W = 2.76 \log L^* - 4.06$ | Kerguelen | Hureau 1970 |
| *N. rossii marmorata* | $W = 0.029L^{2.85}$ | South Georgia | Crisp & Carrick 1975 |
| *N. magellanica* | $\log W = 2.87 \log L^* - 4.20$ | Kerguelen | Hureau 1970 |
| *Pseudochaenichthys georgianus* | $W = (0.213L)^3$ | Scotia Sea | Dubrovskaya and Makarov 1969 |
| *Chaenocephalus aceratus* | $W = (0.189L)^3$ | Scotia Sea | Dubrovskaya and Makarov 1969 |
| *Channichthys rhinoceratus* | $W = 47.8 \times 10^{-6} L^{2.75}$ | Kerguelen | Hureau 1966 |

(1) This equation does not fit the results of Dubrovskaya and Makarov (1969) who worked on fish from the same hauls. An approximate conversion ratio based on their results is $W = (0.2L)^3$

W = Total Weight (g)
L = Total Length (cm)
L*= Standard Length (cm)

## 8.5 Reproduction

There are in the literature few published accounts of seasonal reproductive cycles but the detail that is presented in them has meant that the main patterns identified can be used to provide a reasonable description for those species for which only limited information is available.

Hureau (1964) used the factor "Relative Gonad Size" (gonad weight as a percentage of total weight) from monthly samples to describe the gross cycle in the gonads of Trematomus bernacchii. From these results and the results from several other species of Nototheniid (Hureau 1970, Everson 1970) it is possible to outline a generalised pattern for the ovarian cycle. This is indicated in Fig. 8.2.and with only slight adjustment of the (y) axes could be applied to most of the Nototheniids investigated (Notothenia neglecta (from Scotia Arc), N. rossii, N. magellanica, Trematomus bernacchii, T. hansoni). The exceptions are Notothenia neglecta at Terre Adelie which produces small diameter ova and therefore does not have such a clearly defined cycle and N. cyanobrancha for which there are two spawning periods (those maturing for the first time spawn in January and those that have spawned previously subsequently spawn in May, (Hureau 1970)).

Information on egg size, fecundity and spawning period for those species of potential commercial importance is given in Table 8.19 and this has been combined with information for all Antarctic species to describe major spawning types (Table 8.20).

It is a characteristic of Antarctic fish to produce large yolky eggs and this has been discussed by several authors (Marshall 1953, Andriashev 1965, Permitin 1971, 1973). It is generally considered that large yolky eggs spawned in the Autumn or early winter months will result in the production of post larvae in the Spring coincident with the phytoplankton bloom. These large eggs are also generally considered to be pelagic (or benthopelagic in some cases). The release of large eggs in the spring by Trematomus sp. may indicate a much slower development rate of the eggs and early larvae although there is no proof of this suggestion.

Table 8.19. Egg size, fecundity and spawning period for Antarctic fish

| Species | Egg dia. mm | Fecundity x $10^3$ | Spawning Period | Reference |
|---|---|---|---|---|
| Micromesistius australis | | | Spring | Hart 1946, Weiss 1974 |
| Merluccius hubbsii | 0.8–0.9(P) | | December | Ciechomski and Weiss 1973 |
| Notothenia gibberifrons | | 50 - 100 | Jul-Aug | Permitin & Sil'yanova 1971 |
| N. neglecta | 3.0(D) | 10 - 30<br>(12/g Total Weight) | May | Everson 1970 |
| | 3 | 10.1 - 14.7<br>(8-16/g Total Weight) | | Permitin & Sil'yanova 1971 |
| | 1.2 | 20-30(13-20/g Total Weight) | January | Hureau 1970 |
| N. rossii rossii | 3(D) | 46-53(15-17/g Total Weight) | May | Hureau 1970 |
| N. rossii marmorata | 4.8(D) | 20 - 120 | Apr-May | Permitin & Sil'yanova 1971 |
| N. magellanica | 1.2(P) | 60 -70<br>(50-58/g Total Weight) | Feb/March | Hureau 1970 |

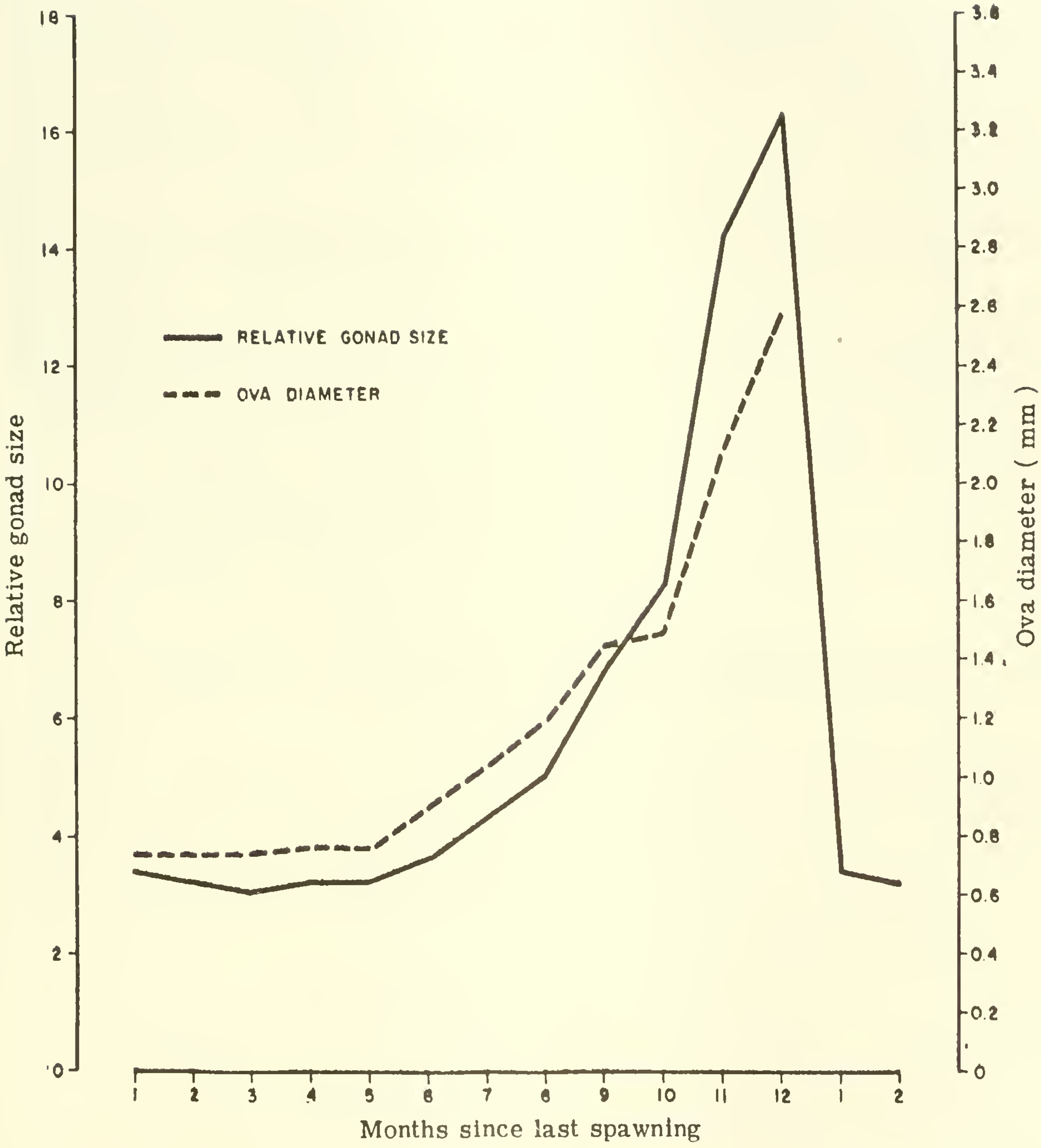

Fig.8.2 Generalized pattern of changes in the ovary of Antarctic notothenide in the pre-spawning period

A series of subjective stages in the gonad cycle of Nototheniids has been described by Everson (in press) based on the ovarian and testis cycles in Notothenia neglecta (Tables 8.21, 8.22).

Table 8.21 Stages in ovarian maturation of Nototheniids based on the cycle in Notothenia neglecta

| Maturity Stage | Description |
|---|---|
| 1. Immature | Ovaries small, firm, no eggs visible to naked eye |
| 2. Maturing Virgin | Ovaries about 1/4 length of body cavity, firm, full of small eggs |
| 3. Developing | Ovaries large, contain eggs of two sizes |
| 4. Gravid | Ovary large. When opened, large ova spill out |
| 5. Spent | Ovary flaccid, contains a few large and many small ova |

Table 8.22 Stages in the testis cycle of Nototheniids based on the cycle in Notothenia neglecta

| Stage | State | Description |
|---|---|---|
| 1. | Immature | Testis very small and translucent, lying close to vertebral column |
| 2. | Developing | Testis small (about 1% total weight), white and convoluted |
| 3. | Developed | Testis large, white and convoluted. No milt produced when pressed or cut |
| 4. | Ripe | Testis large, opalescent white. Drops of milt produced under pressure or when cut |
| 5. | Spent | Testis much smaller and flabbier than stage 4, dirty white in colour |

Table 8.19. (continued)

| Species | Egg diam. mm | Fecundity x $10^3$ | Spawning Period | Reference |
|---|---|---|---|---|
| *Dissostichus mawsoni* | 4-4.3(D) | | (Nov/Dec)$^1$ | Yukhov 1971a |
| *Champsocephalus* | 1.9-2.2 | | April | Olsen 1955 |
| *Champsocephalus* | 3.4-4 | | May | Lönnberg 1905 |
| *Champsocephalus* | 2.6 | 4-23 S. Georgia | | Permitin 1973 |
| | | 8 S. Orkneys | | Permitin 1973 |
| *Chaenocephalus* | 4.7 | S. Orkneys | (June) | Everson 1968 |
| | 3.9 | S. Georgia | Mar/Apr | Permitin 1973 |
| *Channichthys rhinoceratus* | 4.5 | 6 - 14 | Feb/Mar | Hureau 1966 |
| *Pseudochaenichthys* | 4 | 5.8-10.9 | Mar/Apr | Permitin 1973 |
| *Chionodraco* | 3.7-5.0 | 2.5-4 | Mar/Apr | Permitin 1973 |

Notes: 1. Comparison of the process of final ovarian maturation in this species with *N. neglecta* from Signy Island suggests that spawning occurs in the middle of winter and not Nov/Dec.

P = Pelagic Eggs

D = Demersal Eggs

Table 8.20. Egg size and spawning time for Antarctic fish

| Spawning Period | Egg Size (mm) | Species |
|---|---|---|
| Spring (Nov. Dec.) | 2.5 - 3.5 | *Trematomus bernacchii*, *T. hansoni* |
| Summer (Jan. Feb.) | 1 | *Notothenia neglecta* (Terre Adelie)<br>*N. magellanica* |
| Autumn (Mar.-June) | 2 - 4 | *Notothenia nudifrons*<br>(*N. angustifrons*)<br>*N. neglecta* (Scotia Arc)<br>*N. rossii*<br>*N. kempi*<br>*N. gibberifrons*<br>*N. larseni*<br>(*Dissostichus mawsoni*)<br>*Champsocephalus gunnari*<br>*Chaenocephalus aceratus*<br>*Pseudochaenichthys georgianus*<br>*Chionodraco* sp.<br>*Channichthys rhinoceratus* |

Hureau 1966, 1970; Everson 1970; Permitin 1971,1973; Keysner *et al.*, 1974

The seasonal cycle in the ovary of all fish species so far studied, whereby there is a steady build up of eggs all of the same size, indicates that spawning seasons of limited duration are normal. The result of this is that it is to be expected that just prior to and during spawning the mature fish will be congregated together. That this occurs is undoubtedly the case as concentrations of mature fish have frequently been caught on the continental shelf of some of the island groups. The approximate localities and environmental characteristics of these localities are summarised in Table 8.23. It should be borne in mind that the list only includes localities where prespawning or spawning fish have been caught and obviously does not include all spawning areas. It is probably fair to assume that spawning concentrations will occur in similar circumstances to those described in the table over most of the range of each individual species.

Table 8.23. Spawning localities and environmental characteristics of spawning grounds.

| Species | Spawning locality | Environmental Characteristics | | | References |
|---|---|---|---|---|---|
| | | Depth(m) | Temp. °C | | |
| *Micromesistius australis* | Patagonia | | | Southern part of Patagonian - Falkland Shelf | Shubnikov *et al.* (1969) |
| *Notothenia gibberifrons* | S.G. | 115-600 | 0.7 to 1.7 | Shelf | Permitin and Sil'yanova (1971) |
| | S.O., S.S. | 115-750 | -0.1 to -0.4 | Shelf | |
| *N. neglecta* | S.O.,(SG)(SS)Shelf | 10-450 | -0.4 to -1.8 | Shelf | Everson (1970) |
| *N. rossii marmorata* | S.G., Shelf | 120-350 | 0.7 to 1.7 | North and East side of Island | Permitin and Sil'yanova (1971) |
| *N. rossii rossii* | Kerguelen Shelf | 250-350 | 1.8 to 2.0 | Rocky shelf SE of Island | Keysner *et al.* (1974) |
| *Champsocephalus gunnari* | S.G. Shelf | 100-125 | 1.2 to 1.6 | In Fjords and shallow parts of Shelf | Permitin (1973) |
| *Pseudochaenichthys georgianus* | S.G. Shelf | 115-350 | 1.4 to 1.7 | Shelf to N,S &E | Permitin (1973) |
| *Chaenocephalus* | S.G. Shelf | 115-350 | 1.2 to 1.5 | Shelf to N,S &E | Permitin (1973) |

(S.G.: South Georgia; S.O.: South Orkneys; S.S.: South Shetlands)

Mention has already been made of the slow growth rate of Antarctic fish. A direct result of this is that sexual maturity is not reached until the fish are several years old. Information on size and age at sexual maturity is set out in Table 8.24. Precise information is not available for most species and several are estimated from the information in the literature.

Spawning migrations have been described in few species although there are indications generally based on negative evidence that several other species perform spawning migrations. Keysner *et al.* (1974) described a migration of *N. rossii* in May from the feeding ground north of Kerguelen to the spawning grounds to the south of the Island. The spawning grounds are characterised by high oxygen content and a rocky substrate. The migration itself is thought to be in the same direction as the prevailing current which in the area has a strength of o.6 to 1.0 kt. The post spawning northward movement in August back to the feeding grounds is thought to be made in a northerly flowing current offshore of the southward flowing current of the spawning migration.

Table 8.24. Age and Size at Sexual Maturity for Antarctic Fish.

| Species | Sex | Sexual Maturity | | | Locality | Reference |
|---|---|---|---|---|---|---|
| | | Age | Length (cm) | Weight (g) | | |
| *Raja georgianus* | ♀ | | 60 | | South Georgia | Permitin 1969 |
| *Micromesistius australis* | ♂ | (4)[1] | 45.3 | | Scotia Sea | Shubnikov *et al.* 1969 |
| | ♀ | (3)[1] | 46.4 | | | |
| *Notothenia gibberifrons* | ♀ | | 35(2) | 400 | South Georgia | Permitin and Sil'yanova 1971 |
| *Notothenia neglecta* | ♂ | 8 | 30 | | Signy Island | Everson 1970 |
| | ♀ | 7 | 29 | | Signy Island | |
| | ♂ | 7 | 18 | 190 | Terre Adelie | Hureau 1970 |
| | ♀ | 8 | 22.5 | 300 | Terre Adelie | Hureau 1970 |
| *N. rossii* | ♂ | 7 | 48 | 1 700 | Kerguelen | Hureau 1970 |
| | ♀ | 8 | 55 | 2 700 | Kerguelen | |
| *N. rossii marmorata* | ♂ | 5(min) | 40(min) | | South Georgia | Olsen 1954 |
| | ♀ | 6(min) | 45(min) | | | |
| *N. magellanica* | ♂ + ♀ | (6-7) | 25 | 500 | Kerguelen | Hureau 1970 |
| *Champsocephalus* | | 4 | | | South Georgia | Olsen 1954 |
| *Champsocephalus* | ♂ | 4 | 21-26 | | South Georgia | Permitin 1973 |
| | ♀ | 4 | 21-25 | | South Georgia | |
| *Chaenocephalus* | | (9)[3] | | | South Georgia | Olsen 1954 |
| *Channichthys rhinoceratus* | | 5 | 34 | 435 | Kerguelen | Hureau 1966 |
| *Pseudochaenichthys* | ♂ | 4-6 | 40-48 | | South Georgia | Permitin 1973 |
| | ♀ | 4-6 | 44-50 | | South Georgia | |
| *Chionodraco* | ♂ | | 31-36 | | | Permitin 1973 |
| | ♀ | | 33-37 | | | Permitin 1973 |

1) This is inferred since the authors state that only sexually mature fish were caught.

2) In this paper mention is made only of mature fish; the size quoted is of the smallest specimen. By comparison with my own unpublished observations at Signy Island this would approximate to the size at sexual maturity.

3) All the fish were sexually mature and aged 9 or more.

Catch rates of *Champsocephalus gunnari* at South Georgia clearly indicate that this species moves inshore to spawn. Olsen (1955) failed to catch any for several months during the summer but then obtained some good hauls towards the end of March. This pattern of occurrence has been confirmed in recent years by members of British Antarctic Survey fishing in Cumberland East Bay, South Georgia. A similar migration has been described for *Channichthys rhinoceratus* by Hureau (1966) although for this species the shoreward movement begins in February.

Both *Merluccius hubbsi* and *Micromesistius australis* outside the Antarctic zone spawn during the spring. Hart (1946) showed that *Merluccius hubbsi* on the Patagonian Shelf moves inshore during October and November and Ciechomski and Weiss (1973) describe spawning in December. They also state that the eggs are 0.8-0.9 mm diameter and are pelagic (Ciechomski and Weiss 1974). The plankton survey from which the above information was derived was conducted between latitudes 42° and 47°S off the Argentine coast and eggs were found throughout the region. In view of the fact that sexually mature fish have been caught in the Scotia Sea in January (Mikheyev 1967) it seems highly likely that in view of the distance between these two areas spawning occurs south of 47° although there is no direct information available.

Hart (1946) suggested that *Micromesistius australis* spawns during the spring and Weiss (1974) has confirmed this from examination of a collection of larvae. Weiss (1974) also considers that spawning occurs deeper than 150 m although no specific area is mentioned.

The presence of mature *Micromesistius australis* in the Scotia Sea during the Antarctic summer is assumed to indicate that this species migrates into the area from the Patagonian region. However, although this explanation fits the observed seasonal distribution of the species in the Southwest Atlantic, it is not confirmed as it is possible that spawning concentrations in the deep shelf zone have as yet gone undetected.

The literature on larval stages of other Antarctic fish is limited to a few papers describing small collections (e.g., Regan 1916, Nybelin 1951, Everson 1968, Hureau 1970). There is no detailed study of development rates although suitable material almost certainly exists in plankton samples.

### 8.6 Feeding

Although a detailed analysis of feeding is outside the scope of the present report, some comment should be made in order to gain a better idea of the position of fish in the ecosystem. Available information for those species of potential commercial importance is tabulated in Table 8.25. The preponderance of Nototheniids, a predominantly demersal group, largely explains the high frequency of benthic organisms in the diet. The presence of planktonic organisms as well indicates that for some species at least there is probably some diurnal vertical feeding migration or else opportunistic feeding on planktonic organisms migrating down. Examples of the former are probably *Notothenia rossii* and *Champsocephalus gunnari* (see Fischer 1976) and of the latter, *Raja georgianus* and *Notothenia neglecta*.

### 8.7 Exploitation

#### Total Catch

In recent years the total reported catch within the FAO Statistical areas for the Southern Ocean (Areas 48, 58 and 88) has been zero. The reason for this is the two areas known to be heavily fished (South Georgia and Kerguelen) are presently included in statistical reporting areas to the north (41 and 51 respectively). In addition, of the species considered in this review only two have been reported as separate species in the FAO Yearbook of Fishery Statistics. These are Southern Poutassou (*Micromesistius australis*) and Patagonian Hake (*Merluccius hubbsi*). There is therefore no precise information available although it has been suggested (Hureau 1973 and Laws unpublished Report) that catches in some areas have been quite large. The following analysis is therefore based on interpretation of the reported catch in relation to the known fisheries of the area.

The reported catch of Southern Poutassou in recent years is set out in Table 8.26.

Table 8.25. Diot of Antarctic Fish.
Figures the percentage frequency occurrence of a particular item.

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Algae | | x | / | | | | | | 18 | 34 | | | | | | | | | | |
| Polychaeta | 10 | 29 | / | | | | | | 6 | 3 | | | | x | | | | | | |
| Gastropoda | | | / | | | | | | 1 | 8 | | | | | | | | | | |
| Bivalvia | | 3 | / | | | | | | x | 19 | | | | | | | | | | |
| Cephalopoda | 2 | 2 | / | | | | | | | | | // | / | | | | | | | |
| Amphipoda | 6 | 10 | // | | | / | | | 40 | 19 | | | | x | | | | / | | |
| Isopoda | 3 | 9 | // | | | / | | | 51 | 40 | | | | | | | | | | |
| Decapoda | 18 | 3 | / | | | / | | | 6 | 24 | | | 7 | | | | 10 | | | |
| Other Crustacea | | 1 | / | | | / | | | | 4 | | | | 1 | | x | | | | |
| Echinodermata | 1 | 6 | | | | | | | | | | | | | | | | | | |
| Other Benthos | | 1 | / | | | | | | | | | | | | | | | | | |
| Cinderia/ Ctenophone | 1 | 8 | / | 82 | 3 | | / | / | | | | | | x | | | | | | |
| Parathemisto | | 1.5 | | 1.5 | 3 | | / | / | | | | | | 24 | xx | | | | | |
| Euphausia | 10 | 11 | / | 4 | 30 | | // | / | 6 | | // | | 1 | 38 | // | 48 | 11 | | // | // |
| Mysidecea | 24 | 5 | / | 1 | 8 | | / | | | | | | 7 | 30 | | 2 | 48 | | | |
| Salps | | x | | | 1 | | / | / | | | | | | | | | | | | |
| Fish | 16 | 1.5 | / | | 3 | / | | | 38 | 16 | | / | 84 | 3 | | 40 | 15 | // | | |
| | SG | SG | SO | SG | SG | SG | SG | K | K | K | O | O | SG | SG | SG | SG | SG | SG | O | SO |
| | (1) | (1) | (2) | (3) | (3) | (1) | (4) | (5) | (6) | (6) | (7) | (3) | (1) | (1) | (4) | (1) | (1) | (9) | (10) | |
| | Raja georgianus | Notothenia gibberifrons | Notothenia neglecta | N. rossii marmorata | | juv | Adult | N. rossii rossii | Juvenile | N. magellanica | | Dissostichus mawsoni | Dissostichus eleginoides | Champsocephalus | | Pseudochaenichthys | Chaenocephalus | | Pleurogramma | Micromesistius |

References for Table 8.25

| | | |
|---|---|---|
| 1. | Permitin and Tarverdiyeva | 1972 |
| 2. | Everson | (unpublished results) |
| 3. | Tarverdiyeva | |
| 4. | Olsen | 1954 |
| 5. | Keysner *et al.* | 1974 |
| 6. | Hureau | 1970 |
| 7. | DeWitt | 1971 |
| 8. | Yukhov | 1971 a |
| 9. | Olsen | 1955 |
| 10. | DeWitt and Hopkins | (in press) |
| 11. | Permitin | 1969 |

| | |
|---|---|
| SG | South Georgia |
| SO | South Orkney Islands |
| K | Kerguelen |
| O | Oceanic |
| x | Present but not quantifiable |
| / | Present |
| // | Dominant item |

Table 8.26. Reported catches of Southern Poutassou (FAO 1976)

(metric tons)

| Area * | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 |
|---|---|---|---|---|---|---|
| 41. S.W. Atlantic | 7 900 | 5 700 | - | - | 3 200 | - |
| 47. S.E. Atlantic | - | - | - | - | - | - |
| 51. S.W. Indian Ocean | - | 4 700 | - | - | 1 900 | 2 081 |
| 57. S.E. Indian Ocean | - | - | - | - | - | - |
| 81. S.W. Pacific | - | - | 25 800 | 48 500 | 42 200 | 2 055 |
| 87. S.E. Pacific | - | - | - | - | - | - |
| TOTAL | 7 900 | 10 400 | 25 800 | 48 500 | 47 300 | 4 136 |
| U.S.S.R. | 7 900 | 10 400 | 25 800 | 48 500 | 47 300 | 4 136 |

* See attached map. No catches have been reported from the Antarctic zones (48,58,88).

The total reported catch of this species has therefore been taken by USSR but it is not clear what proportion (if any) was taken from waters which are considered Antarctic but are nonetheless north of the Antarctic statistical areas. However, since the published records of fishing for this species refer to catches made in the Scotia Sea, it is very probable that the major part of the reported catch for area 51 was made in that area. (See papers by Basalaev and Petukhov 1969 and Mikheyev 1967). It is not possible to make such a distinction for the other areas although the reported catch for area 81 was probably taken from the Campbell Plateau (Shuntov 1971).

The reported catch in recent years of Patagonian Hake is set out in Table 8.27.

Table 8.27. Reported catches of Patagonian Hake (FAO 1976)

metric tons

| Area | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 |
|---|---|---|---|---|---|---|
| 41. S.W. Atlantic | 108 100 | 116 400 | 139 300 | 187 500 | 199 400 | (152 400) |
| Nation | | | | | | |
| Argentina | 87 400 | 92 000 | 102 800 | 151 400 | 162 200 | 109 000 |
| Brazil | 16 700 | 18 200 | 24 000 | 31 600 | 33 600 | (33 600) |
| Germany, Fed. Rep. | - | - | 3 900 | - | - | - |
| Uruguay | 3 700 | 3 700 | 8 500 | 4 500 | 1 500 | 9 800 |
| U.S.S.R | 300 | 2 500 | 100 | - | 2 100 | - |

( ) = Figures in parentheses are estimated by FAO.

The fact that the bulk of the catches of this species were made by nations whose coastline borders the statistical area 41 suggests very strongly that only a small proportion (if any) was taken in Antarctic waters.

Concerning the other species (mainly Nototheniiforms), those catches that have been made are probably included under the general heading of unspecified demersal Percomorphs. The statistics for this group are summarized in Table 8.28.

Table 8.28. Reported catches of unspecified demersal Percomorphs (FAO 1976)

metric tons

| | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 |
|---|---|---|---|---|---|---|
| Antarctic and adjacent areas. | 450,300 | 272,900 | 152,700 | 58,600 | 160,632 | 67,185 |
| Total world reported. | 537,900 | 393,900 | 299,300 | 208,800 | 433,198 | 348,081 |

Fishing vessels of the USSR have been seen fishing in the vicinity of South Georgia (statistical area 41 S.W. Atlantic) (Laws per. comm.) and also off Kerguelen (statistical area 51 S.W. Indian Ocean) (Hureau 1973). From observations of the number of fishing and support vessels in the vicinity of Kerguelen, Hureau (1973) estimated that 120 000 tons of fish (probably Notothenia squamifrons, N. rossii, Channichthys rhinoceratus and Champsocephalus gunnari) were taken during the 1971/72 season. At South Georgia the principal fish species caught is probably Notothenia rossii (my own observations on ships visiting the islands). The reported figures for areas adjacent to Antarctica follow the known distribution of fishing vessels of the USSR in Antarctic waters which strongly suggests that a significant part of this catch is Antarctic Nototheniiform fish (Table 8.29).

In addition exploratory fishing expeditions have gone to the Antarctic from West Germany, Japan and Poland; the total catch of each is very small at the moment. It is not known whether any other nations are taking fish on a commercial scale.

Assuming the above estimates are correct it indicates the inadequacy of the present reporting systems for two reasons; firstly because two of the major fishing areas (South Georgia and Kerguelen) lie outside the present Antarctic statistical regions and secondly the catch of Percomorphs is not broken down into its specific components. An improved format for reporting has therefore been produced (See section 11.2).

Table 8.29. Reported catch of unspecified demersal Percomorphs (FAO 1974,1976).

(metric tons)

| Area | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 |
|---|---|---|---|---|---|---|---|---|---|---|
| 41 USSR | 1,100 | 12,900 | 5,400 | 89,100 | 404,800[x] | 16,300 | 2,300 | 400 | 3,900 | - |
| Total | 3,400 | 14,800 | 7,500 | 91,600 | 407,900 | 20,500 | 5,300 | 4,000 | 8,300 | (7,100) |
| 47 USSR | 1,000 | 1,600 | 10,300 | 8,000 | 9,000 | 7,400 | 11,100 | 7,000 | 7,965 | 6,816 |
| Total | 1,000 | 1,600 | 10,300 | 8,000 | 9,000 | 7,900 | 11,900 | 8,000 | 20,065 | 16,895 |
| 51 USSR | 11,400 | 5,300 | 1,300 | 900 | 12,800 | 212,300[xx] | 102,900[xx] | 9,700 | 87,100 | 18,449 |
| Total | 81,500 | 74,900 | 82,400 | 83,100 | 32,800 | 231,500 | 118,700 | 26,500 | 104,011 | (34,037) |
| 81 USSR | - | - | - | - | - | 10,400 | 14,300 | 18,200 | 25,800 | 5,717 |
| Total | 100 | 100 | 200 | 500 | 500 | 11,000 | 15,100 | 19,300 | 27,176 | 8,800 |

( ) Figures in parenthesis are estimated by FAO.

x Commercial fleets from USSR reported at South Georgia (Laws per. comm.)

xx " " " " " " Kerguelen (Hureau 1973)

Catch Rates

Published information on catch rates is summarized in Table 8.30. It is not known what catch rates were achieved by the recent West German and Polish expeditions although in the case of the former it is thought that the catch rate and maximum haul size were both at least equal to the highest figures quoted.

Table 8.30. Catch rates for Antarctic Fish

| Species | Year | No. of hauls | Mean Catch (t/hour) | Max Catch (t /haul) | Mean Haul Time (min) | Location | Nation | Remarks | Reference |
|---|---|---|---|---|---|---|---|---|---|
| 1, 2 | 1964 | | | 1.5 | | Scotia Sea | USSR | Using krill net/ shrimp trawl | Mikheyev 1967 |
| 2 | 1964 | 3? | | 2-4 | | Patagonia | USSR | Bottom trawl? | Mikheyev 1967 |
| 1 | 1965 | 21 | 2.4 | 10 | 85 | Scotia Sea | USSR | Mid-water trawl towed at 2.7-3.6 km at 25-65 m depth | Basalaev and Petukhov 1969 |
| 1 | 1970? | | | 9½ | 45 | South of New Zealand | Japan | Bottom trawl? in 100 fathoms | Anon. 1971 |
| 3 | 1970 | 17 | | 12 - 20 | | S. Georgia | USSR | Bottom trawl | Tarverdiyeva 1972 |
| 4 | 1976 | | | 17 | 15 | Obov Bank | Japan | | Anon 1976 |
| 3 | 1970 | | 10 | | | S. Georgia | USSR | Bottom trawl | Everson (unpublished BAS report) |
| 3 | 1971 | | 2 | | | S. Georgia | USSR | Bottom trawl | Everson (unpublished BAS report) |
| 5 | 1975 | 38 | 0.55 | | | Shag rocks near South Georgia | Germany, Federal Rep. of | Bottom trawl 15.5 t/h largest haul | Kock 1976 |
| 5 | 1976 | 3 | 0.008 | | | | | | |
| 5 | 1976 | 10 | 0.3 | | | | | | |

1. *Micromesistius australis*
2. *Merluccius hubbsii*
3. *Notothenia rossii*
4. *Notothenia macrocephala*
5. *Dissostichus eleginoides* and *D. mawsoni*

## 8.8 Biomass, Production and Yield

The very recent build-up of fisheries in the Antarctic has meant that only limited information on biomass and production is available and this is dispersed in a variety of publications. There is nowhere in the literature a detailed analysis of information suitable for fishery management decisions. The analysis which follows should be considered as a first approximation (as far as Antarctic endemic fish are concerned) that will require updating as more information from the fishery becomes available. The need for precise reporting of catches by species has been clearly understood for some time in most sea areas and it is hoped that the recommendations in Section 11.2 for the Antarctic areas will result in much improved stock estimates in future years.

The joint ACMRR/CARPAS working group on the fish stocks of South America (FAO 1974) gave information (Table 8.31) for Micromesistius australis and Merluccius hubbsi, the two species that are thought to migrate into the Antarctic.

Table 8.31. Fish Stock assessments for Patagonian species which migrate into the Southern Ocean (Data from FAO 1974)

| Species | Biomass (t) | Optimum Sustainable yield (t) | Catch 1972 (t) | Catch 1974 (t) |
|---|---|---|---|---|
| Merluccius hubbsii | 3-6 million | 200 000 - 1 800 000 | 125 000 | 190 000 |
| Micromesistius | ? | 800 000 or more | insignificant | 3 200 |

The working group considered the Hake as consisting of several distinct management stocks limited geographically. The above results relate to the most northern group (35 - 45°S) which represents the greater part of the present fishery. It is not clear how these figures can be applied to the southern end of the range, but in view of the slower growth rate suggested by Mikheyev (1967) the optimum sustainable yield is likely to be less in proportion to the biomass at the higher latitudes. There is no information on biomass in the Southern Ocean or on the proportion of the southern stock that migrate further south.

The estimates for Micromesistius are clearly based on very limited information and as with Merluccius there is no information to indicate the proportion of the population migrating south. This information is not likely to become available until commercial fishing takes a much larger proportion of the optimum sustainable yield. Regarding these two species since the available evidence suggests that they are migratory species it is probably best for the time being to assume that catches from the Scotia Sea area are of Patagonian fish.

There is no information on which to base estimates of MSY for stocks of Micromesistius at Kerguelen or South of New Zealand. This should become a management priority now in view of the reported catch of over 40 000 tons in area 81 ; this was probably taken from the Campbell Plateau area (see Shuntov 1971).

In the section 8.7 it was suggested that a large proportion of the reported catch of "Unspecified Demersal Percomorphs" in some areas adjacent to Antarctic waters was largely made up of Antarctic Nototheniiforms. There is no firm confirmation of this fact, but all available evidence indicates that this is correct.

Reported catches in Area 41 show a rapid build up to a peak of over 400 000 t followed by a rapid decline to a few thousand tons the following years. The decline in total catch can be attributed to two causes, fewer vessels and/or a lower catch rate. The very great reduction in catch rate from 10 to 2 ton/hr indicates a great reduction in stock density. This factor in itself suggests that the total catch in the first few years was something approaching the initial standing stock level. Ignoring natural additions to the population, and assuming that the change in catch rate accurately reflects an 80% drop in population, then the catch would have been 80% of the initial stock. This suggests an initial standing stock of about 500 000 t for the South Georgia Shelf area.

In area 51 (assumed to refer to Kerguelen) the more gradual decline in reported catch suggests that the highest figure was appreciably less than the initial standing stock whilst at the same time since the catches have declined from year to year they are probably still (1974) higher than the MSY. These catch figures therefore indicate an initial standing stock of well in excess of 220 000 and an MSY of less than 80 000 ton/yr.

Information on fish biomass production is available from two additional sources. Everson (1970a) in a detailed analysis of Notothenia neglecta in a small area (part of Borge Bay, Signy Island) estimated that the mean biomass was 194 kg/hectare and that annual production was 66 kg/hectare. The annual production in this study was estimated over the whole demersal phase of the lifespan.

Production by sexually mature fish was only about one third of this. Although this figure is very probably an overestimate of production by the fishable stock there is no information to indicate where a more realistic demarcation should be made. A second estimate of fish production in the Southern Ocean is given by the estimated annual consumption by predators. Estimates for fish consumption by whales, seals and birds have been made by Laws (1977) and Croxall (unpublished MS). These are summarised in Table 8.32.

Table 8.32. Consumption of Antarctic fish by Whales, Seals and Birds
(Data from Laws 1977, and Croxall unpublished MS)

| Group | Fish Consumption in Antarctic (thousands ton/yr) | |
|---|---|---|
| | Initial Stocks | Present Stocks |
| Whales | 4 410 | 1 129 |
| Seals | ? | 7 685 |
| Birds | ? | 6 750 |
| Total | ? | 15 564 |

---

[1] Since preparing these estimates my attention has been drawn to a study of the fish stocks in the Kerguelen area. Hureau (in press) using results from a trawling survey estimated the standing stock of demersal fish to be about 120 000 t and their MSY to be about 20 000 t (or about 0.4 t/km$^2$ of shelf area). The disparity between his results and those presented above, is a further indication of the incomplete nature of most of the information necessary for these assessments and underlines the importance of reported catch statistics for fish stock assessments.

The total figure in Table 8.32 is made up of all Antarctic fish species and not just those of potential commercial importance. Total production by those species of potential commercial importance is therefore likely to be less than this figure although by how much is not known. The growth patterns of the fish species within the area, since most belong to the same taxonomic group (Nototheniiforms), may well follow the same sort of pattern. This being the case, the production by sexually mature fish is probably about one third of the total (i.e., about 5 million tons).

The tendency for Antarctic fish to produce large yolky demersal eggs indicates a reliance on the Continental or Island Shelf areas for at least part of their life histories. South of the Antarctic Convergence the Continental and Island Shelves cover an area of approximately 2.2 x $10^6$ $km^2$ [1]. The total production estimated from consumption by predators averaged over the shelf area is 7.75 ton/$km^2$.

The fact that this figure is only slightly larger than the production figure for Notothenia neglecta should not be taken as any indication of precision since both estimates are subject to considerable error because one applies to one species (the dominant one in the study area) in a restricted shallow water area and the other relates to all species over the whole Southern Ocean. The figures should be taken as only an indication that they are of the right order of magnitude rather than being truly representative of the actual situation.

If these figures of production are applied to the 36 000 $km^2$ (approx.) of the South Georgia Shelf area, the estimated figures for that area are 230 000 - 280 000 ton production. The production figure applies to the whole demersal lifespan and since only about 1/3 of this is due to sexually mature fish the production that is of interest to a fishery would be 77 000 ton/yr, and since the stock of sexually mature fish is almost certainly greater than the fishable stock these figures must be overestimates.

These estimates have been summarized in Fig. 8.3.

Erring on the side of caution and therefore taking the lowest figure, a MSY of 50 000 ton/yr is indicated for the South Georgia area.

In the absence of any more sophisticated or precise estimates of production the same estimates if applied to the Kerguelen shelf area (approx. 50 000 $km^2$) indicate a total production of 230 000 to 300 000 tons and a production of sexually mature fish of from 77 000 to 100 000 tons. Assuming that the lower figure is a reasonable estimate of MSY this figure is approximately what would be expected from intuitively inspecting the reported catch in recent years (see Table 8.27).

It is important to bear in mind that the production figures discussed above apply, with the exception of those for Notothenia neglecta at Signy Island to all fish within the Antarctic zone. Although the Signy Island study was undertaken on only one species, it is fairly certain that within the area of the investigation Notothenia neglecta was by far the dominant species in terms of biomass. The suggested MSY for South Georgia and Kerguelen are therefore a total for all species in the particular areas. Without knowledge of the proportion of species present it is impossible to partition the MSY even between major groups.

**In the absence of any further information, it is reasonable to assume that a figure of approximately 1.5 ton/$km^2$ (see footnote to p.110) is applicable to the other shelf areas.**

---

[1] This figure excludes the major ice shelf zones.

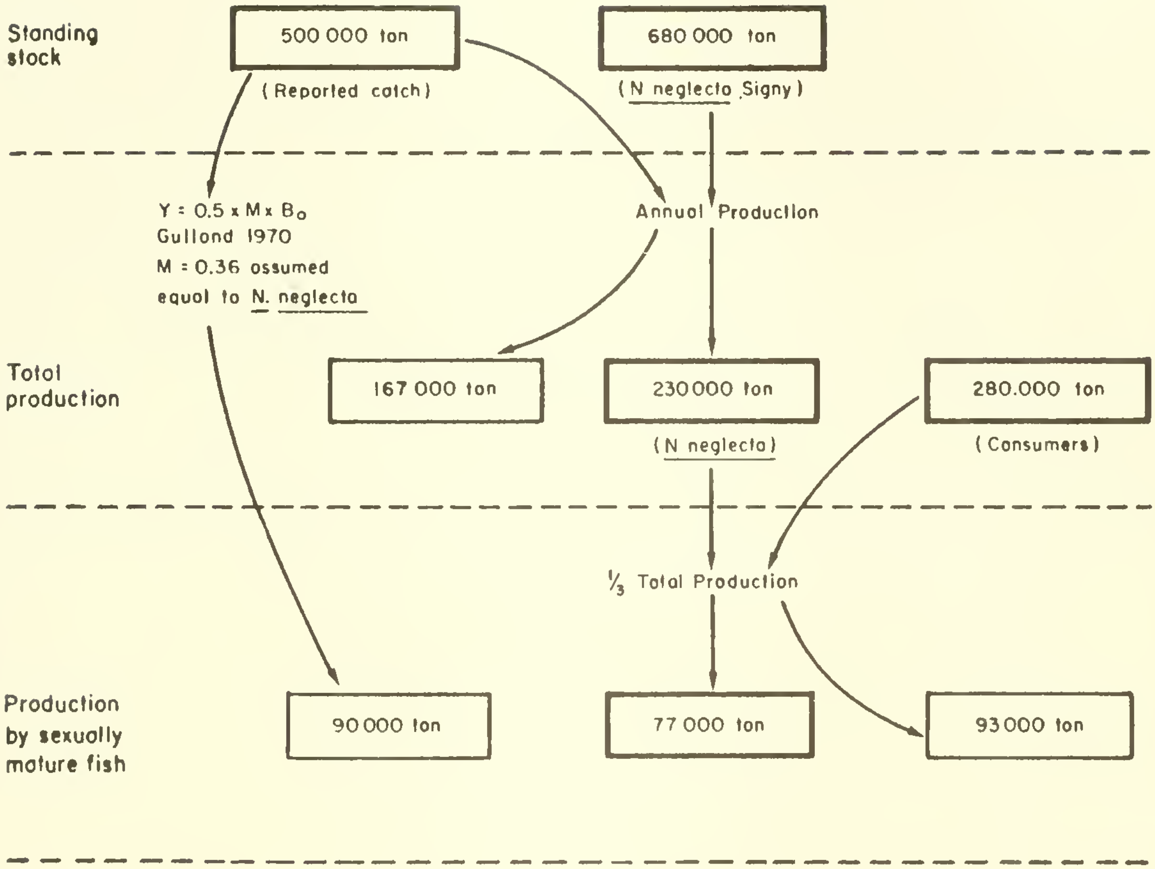

Fig.8.3 Diagrammatic estimation of biomass and production of fish around South Georgia.
(Figures in heavy-lined boxes are based on direct estimates; figures in lighter-lined boxes are based on estimates calculated by the factors shown (see text))

# APPENDIX H

## Biological Investigation of Marine Antarctic Systems and Stocks

# BIOLOGICAL INVESTIGATIONS OF MARINE ANTARCTIC SYSTEMS AND STOCKS (BIOMASS)

## Volume 1: Research Proposals

*Prepared by*

Scientific Committee on Antarctic Research (SCAR)
Scientific Committee on Oceanic Research (SCOR)
Group of Specialists on Living Resources
of the Southern Ocean
SCOR Working Group 54
(Convenor: Sayed Z. El-Sayed)

August 1977

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# FOREWORD

The foundation of our knowledge of the biology of the oceans surrounding the Antarctic continent was laid in the 1930's by the *Discovery* expeditions and other oceanographic investigations related to the whaling industry. During the 1960's much of the marine biological work was confined to waters relatively close to land, although some open sea investigations were made, notably by the USA, USSR and Japan. SCAR has promoted with SCOR two international symposia, one in 1966 and one in 1970, on Antarctic oceanography, both of which included papers and discussion on biology and physics.

In the early 1970's the potential for exploiting the living resources of the region other than the whales and seals was beginning to attract interest. While it was realized that some years of experimental fishery and technological development would be necessary before exploitation on a large scale would become an attractive proposition, SCAR foresaw the need to expand substantially scientific understanding of the oceans and in particular the relationship between potentially exploitable species and other elements of the marine ecosystem.

The BIOMASS document presents a proposal for the long term intensification of scientific research, the results from which will provide the scientific foundation on which to base advice on rational control of the stocks in order to prevent over-exploitation and to ensure maximum annual yields. I therefore recommend the implementation of the proposed programme of research to all concerned, before any large scale exploitation interests develop.

As President of SCAR, I am pleased to record the collaboration in this endeavour of the Scientific Committee on Oceanic Research and the International Association of Biological Oceanography of IUBS, and the co-operation of the Advisory Committee on Marine Resources Research of FAO, the Intergovernmental Oceanographic Commission of UNESCO, and the consultative parties to the Antarctic Treaty.

Financial support has been provided by the International Council of Scientific Unions, and I also wish to acknowledge the generous contributions of the US National Academy of Sciences and the US National Science Foundation, who provided the excellent facilities at Woods Hole for the conference of experts and substantial support for the production of the BIOMASS proposal.

Finally I should like to record my personal appreciation and the gratitude of the international Antarctic scientific community to Dr Sayed Z. El-Sayed, the Convenor of the SCAR/SCOR Group of Specialists, for the great effort that he has devoted to arranging the meetings and organizing the production of the text of this report. My thanks go also, of course, to the members of his group for their contributions.

T. Gjelsvik
President of SCAR

# PREFACE

This document represents four years of effort by several members of the SCAR nations to develop a co-ordinated international programme for the study of the living resources of the Southern Ocean. This effort began in August 1972, in Canberra, Australia, with the establishment of a subcommittee of the Biology Working Group on the Marine Living Resources of the Southern Ocean. The subcommittee met in Montreal, Canada, in May 1974, and in Cambridge, UK, in October 1975. At the latter meeting the subcommittee (now upgraded to the SCAR Group of Specialists on Living Resources of the Southern Ocean, and from November 1975 cosponsored by SCOR as its Working Group 54) welcomed the offer of the United States to host an international scientific conference on the living resources of the Southern Ocean. The meeting was held in the US National Academy of Sciences Summer Study Center in Woods Hole, Mass, 17–21 August 1976; 59 scientists representing 14 nations participated. The chief objective of the conference, and the following meeting of the Group of Specialists (23–25 August), was to review the present knowledge of the living resources of the Southern Ocean and to develop a proposal for future co-operative studies in this area. A number of background review papers and scientific reports was also presented at the conference and is to be published in a separate volume (*BIOMASS Volume II: Selected contributions to the Woods Hole Conference on Living Resources of the Southern Ocean, 1976*).

The major part of the conference, as well as the subsequent sessions of the Group of Specialists, were devoted to discussions on the development of an international programme for the Biological Investigations of Marine Antarctic Systems and Stocks (BIOMASS). The principal objective of BIOMASS is to gain a deeper understanding of the structure and dynamic functioning of the Antarctic marine ecosystems as a basis for the future management of potential living resources. The BIOMASS proposal described in this report represents the first major international effort to co-ordinate present and future research for the development and wise management of the living resources of the Southern Ocean.

It is important to note in this respect that, at the meeting of the Group of Specialists held immediately after the Woods Hole conference, a set of recommendations, addressed to SCAR, SCOR and IOC, was adopted. These recommendations contain the amended terms of reference of the Group of Specialists, together with a proposed mechanism for practical implementation of the BIOMASS programme at the international level. The recommendations are included in the appropriate parts of the text.

I am indeed grateful to the valuable contributions made by the members of the SCAR/SCOR Group of Specialists on Living Resources of the Southern Ocean in drafting this document. The IABO reviewers of the BIOMASS document deserve much thanks for their helpful and generous suggestions for the proposal's improvement at draft stage. I am also grateful to the participants at the Woods Hole conference for their useful advice at the meeting.

I wish to express my deep thanks and appreciation to the US National Academy of Sciences for hosting the conference at the Academy's Summer Study Center in Woods Hole, Mass. Mr Louis DeGoes, Mr Timothy Hushen and Ms Betty Olsen, of the Polar Research Board, NAS, deserve thanks for their splendid help and co-operation. Finally, I am deeply indebted to Mrs Pamela S. Horne for her invaluable assistance in producing this report.

Sayed Z. El-Sayed
Convenor

College Station, Texas
*3 June 1977*

# 1. INTRODUCTION

## 1.1 Background

### 1.1.1 *Historical background*

In recent years the world has been witnessing a renewed interest in the living resources of the Southern Ocean. Notable among these resources are marine mammals (whales and seals), krill (primarily *Euphausia superba*), fishes, squids, spiny lobsters, crabs and seaweeds (Fig 1). For hundreds of years the cold waters of the Northern Hemisphere have provided the bulk of the world's fish catch. Attention is now being focused on the development and exploitation of the resources of the tropical and Antarctic waters. There is little doubt that compared with the areas of conventional/historical fish production, the Antarctic resources are indeed enormous. The magnitude of these resources and their distribution in the Southern Ocean have been discussed by El-Sayed (1975). As an indication of the richness of one resource, krill, some fishery experts have speculated that 100 million tons of krill could be taken annually without depleting krill stocks. This figure is slightly less than double the 1973 world fish and shellfish catch. A number of countries are now engaged in the exploration of these living resources while several others are planning their future exploitation.

Concern over the need for proper management and conservation of Antarctic marine resources has been voiced by members of the scientific community and national/international agencies and organizations. We are mindful of the tragedies that have befallen the California sardines, the Peruvian anchovies and the Antarctic baleen whales. The concern of the scientists for the conservation of these resources also stems from the fact that we do not have adequate information concerning the stocks of these resources. Despite past research activities we have only very rough estimates of krill stocks. We have virtually no estimates of the abundance and biomass of fish populations in the Antarctic, and we know almost next to nothing about Antarctic squids. Yet, effective conservation and management depend on a continuing flow of data and information regarding these resources.

The problem is further complicated when we consider the structure of the Antarctic ecosystem and the complex interactions between the seals, whales, sea birds, penguins and fishes, all competing for food which consists mainly of krill. And since krill is the key species of the Antarctic ecosystem, it is not difficult to visualize that its unwise exploitation could trigger disastrous changes throughout that ecosystem.

### 1.1.2 *History of establishing SCAR/SCOR Group of Specialists on Living Resources of the Southern Ocean*

As detailed in Section 4, several international bodies have interests in the living resources of the Southern Ocean. Of these organizations, SCAR has played a key role. In August 1972 SCAR established a subcommittee of the Biology Working Group on the Marine Living Resources of the Southern Ocean. The charge of the subcommittee was to assess the present state of knowledge of the Antarctic marine ecosystem and to stimulate investigations of the ecology and population dynamics of the organisms at different trophic levels. The subcommittee held its first meeting in May 1974 at McGill University (Montreal, Canada) in conjunction with the SCOR/SCAR Polar Oceans Conference. At this meeting the subcommittee developed a series of recommendations, one of which stated:

> Because of the significant role played by krill in the Antarctic marine ecosystem, and because of our concern for the wise management of krill

> stocks, we *recommend* that efforts should be made to continue and expand investigations of the biology, ecology and population dynamics of krill, and of the distribution of its swarms. We also recommend that in estimating the size of these stocks, modern techniques such as echo-sounding surveys should be used in addition to net hauls.

In another recommendation, the subcommittee wrote:

> In view of the enormous gaps in our knowledge of the stocks of such potentially important and presently under-exploited fisheries resources as the cephalopods, pelagic and demersal fishes, we *recommend* that in-depth studies of the biology, distribution, biomass and population dynamics of these resources be undertaken.

Perhaps one of the most significant recommendations of the Montreal meeting was Recommendation No 5:

> We call attention to the significance of the biological oceanographic studies in the Southern Ocean as prerequisites for the wise management of these resources. We wish to express our concern at the deceleration of many biological studies aboard research vessels in the southern waters. We realize the enormous difficulties of undertaking the formidable task of studying the marine ecosystem of the vast expanses of the Southern Ocean when only one or two oceanographic ships are utilized. We, therefore, *recommend* that a well co-ordinated International Biological Investigation of the Southern Ocean (IBISO), utilizing multiple ships, be undertaken. The objectives of IBISO might include:
>
> (a) the study of the trophodynamics of the Antarctic ecosystem
>
> (b) the provision of data/information for the conservation and wise management of the living resources of the Southern Ocean
>
> (c) the provision of data/information for monitoring pollutants at all levels in the food web and in the water column.

The Montreal recommendations were later approved by the Thirteenth Meeting of SCAR in September 1974, and by the International Co-ordination Group for the Southern Ocean of IOC at its meeting in Buenos Aires, Argentina, in July 1974. In March 1975, the Executive Council of IOC invited the SCAR subcommittee:

> to prepare practical proposals for collaborative investigations in biological oceanography in the area and to prepare proposals for working toward the organization of multiship studies for submission to SCAR and SCOR and through them to the IOC International Co-ordination Group.

At the Eighth Antarctic Treaty Consultative Meeting held in Oslo, Norway, in June 1975, it was recommended that the governments:

> . . . invite SCAR to continue its scientific work on these matters and to consider convening, as soon as practicable, a meeting to discuss current work and report on progress for the study of conservation of Antarctic marine living resources.

In recognition of these new responsibilities, SCAR, at its executive meeting in June 1975, upgraded the status of the marine living resources subcommittee to a group of specialists. The terms of reference adopted for this group are:

1. To assess the present state of knowledge of the Antarctic marine ecosystem from the point of view of structure, dynamic functions, and biomass of the organisms at different trophic levels.

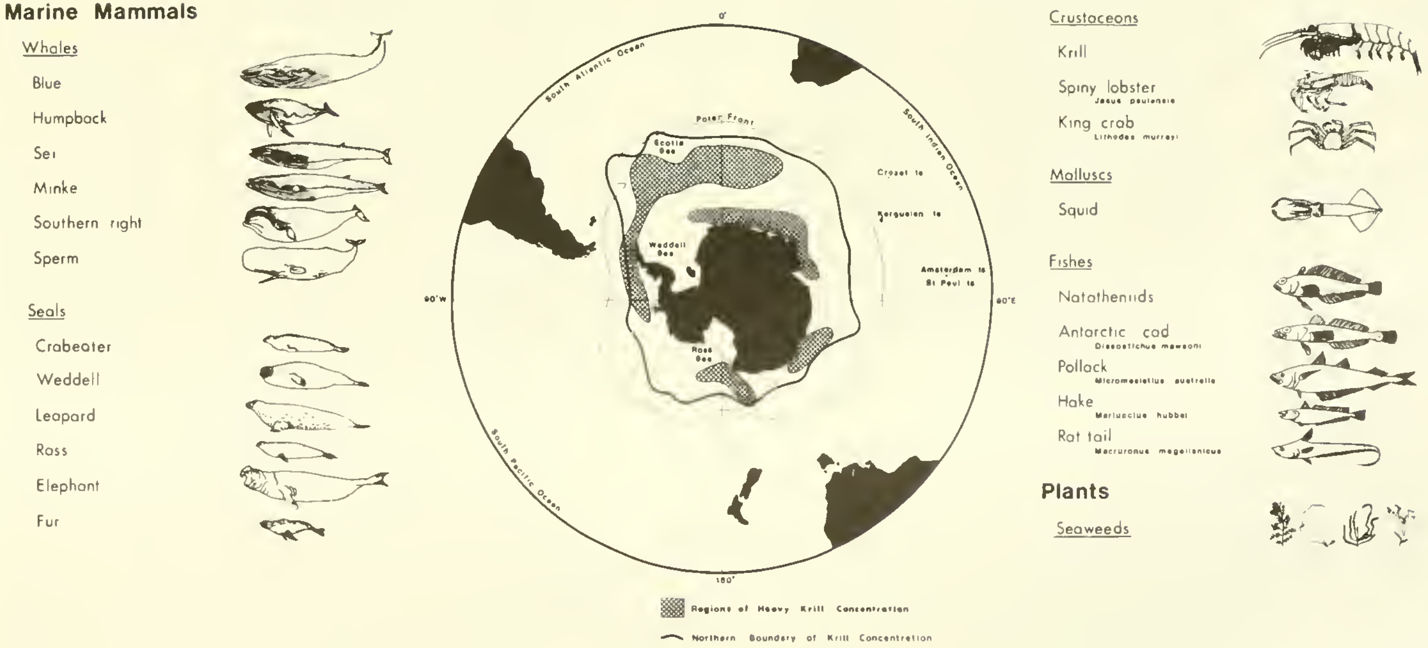

FIG 1. Living resources of the Southern Ocean.

2. To encourage and stimulate investigations of the ecology and population dynamics of the organisms at different trophic levels with particular reference to krill, squid, fishes and whales.
3. To maintain liaison with FAO.
4. To advise SCAR and SCOR and through them other international organizations and in particular to respond to relevant recommendations of IOC and Antarctic Treaty consultative meetings.

At its Executive Committee meeting in November 1975 SCOR, at the invitation of SCAR, agreed to cosponsor the group and adopted it as its Working Group 54.

In order to initiate action in relation to IOC and Antarctic Treaty invitations, the first meeting of the reconstituted Group of Specialists was convened at the Scott Polar Research Institute in Cambridge, England, 6–8 October 1975 (*SCAR Bulletin*, 1976). During this meeting, the group agreed that its first task should be to review all existing information and to bring together knowledge of ongoing and presently planned programmes of marine biological investigations. The group also undertook the preparation of practical proposals for long term co-operative investigations of the Southern Ocean. The group welcomed the offer of the United States to host a scientific meeting on the living resources of the Southern Ocean.

Accordingly, an international conference of experts was held at the US National Academy of Science Summer Studies Center in Woods Hole, Mass, 17–21 August 1976, and was followed by a meeting of the Group of Specialists (23–25 August). The chief objective of both was to review the present knowledge of the living resources of the Southern Ocean and to develop a proposal for future co-operative studies in the area. This proposal is referred to as the Biological Investigations of Marine Antarctic Systems and Stocks (BIOMASS). The research programmes included in BIOMASS are discussed in the following sections.

However, before presenting these programmes, it is imperative to take into account the likely effect of marine pollution on the Antarctic ecosystem and how it relates to the proposed BIOMASS investigations.

### 1.1.3 *Marine pollution*

Recently the question of exploitation of Antarctic mineral resources has come under discussion within the Antarctic Treaty Consultative Meeting and elsewhere. There is a general consensus that possible petroleum and natural gas deposits on the Antarctic continental shelf are the resources most likely to attract interest in the near future. The Eighth Antarctic Treaty Consultative Meeting in 1975 invited SCAR 'to undertake an assessment on the basis of available information of the possible impact on the environment of the Treaty area and other ecosystems dependent on the Antarctic environment if mineral exploration and/or exploitation were to occur there'. SCAR compiled a preliminary assessment as a result of various informal consultations with individual scientists and specialists and by correspondence with SCAR National Committees, based on the experience of scientific investigations in the Antarctic carried out by many nations over a number of years. This was submitted to a special preparatory meeting for the Ninth Antarctic Treaty Consultative Meeting, Paris, June/July 1976, which then invited SCAR to undertake a more detailed assessment, based on existing knowledge, for consideration at the Ninth Consultative Meeting in 1977.

At its Fourteenth General Meeting in October 1976, SCAR expressed its willingness to respond to this invitation and to treat such an assessment as a task closely allied to its main objectives, although the degree of detail achievable in this further assessment would depend on the financial support available. To carry out the task SCAR established a Group of Specialists on Environmental Impact Assessment of Mineral Resource Exploration and Exploitation in the Antarctic (EAMREA), whose activities will fall into two phases:

(a) the preparation of the new detailed assessment requested on the basis of existing knowledge, and the formulation of a long term research programme to fill any serious gaps in knowledge;
(b) the execution of this long term research programme.

It is clear that a considerable amount of research will be needed to assess the likely effects of exploration and exploitation of oil resources on Antarctic ecosystems. While some guidance may be obtained from recent Arctic experience, there will be no substitute for research on Antarctic ecosystems and their component species. There is also a great need for studies in areas of likely activity and for basic information on the biology of key species likely to be affected by oil pollutants. Areas of special sensitivity and/or scientific importance need to be identified and carefully planned monitoring programmes will need to be developed.

From the viewpoint of the Antarctic marine ecosystem, it is clear that the BIOMASS programme will provide much of the baseline and other data required. There will need to be close co-ordination between other SCAR initiatives concerning the possible effects of mineral exploration and/or exploitation in the Antarctic Ocean.

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### 1.2 General objectives

The need for a comprehensive international and interdisciplinary research programme in the Southern Ocean stems from the fact that the circular current system of the Southern Ocean houses a food web which is very different from those of other parts of the world ocean. Individual weights of its key members are larger by several orders of magnitude than comparable ones in other oceans, which provides the incentive for a unique mass exploitation of the Southern Ocean's key herbivore–krill.

The principal objective of the BIOMASS programme is *to gain a deeper understanding of the structure and dynamic functioning of the Antarctic marine ecosystem as a basis for the future management of potential living resources.* Thus, we are primarily concerned with (a) contributions to man's understanding of the world ocean, and (b) developing a sound ecological strategy for the exploitation of the living resources and for the conservation of the Southern Ocean's ecosystem. To achieve these goals of basic marine science and wise ecosystem management we need to consider several objectives. The list given below emphasizes krill as the major potential food resource of the Antarctic waters and as a key element of the marine food web. At the same time, it is recognized that there are other important marine studies in the Antarctic which warrant the attention of the scientific community. BIOMASS will evolve as it proceeds and will hopefully attract new scientists with new ideas in the course of its development into a comprehensive study of the Antarctic ecosystem, its exploitation and conservation.

1. Study of the physical/chemical environment influencing krill and its food base, namely:
    (a) study of vertical advective and diffusive processes, as driving forces of primary production

   (b) study of micro- and meso-scale horizontal processes in relation to swarming of krill and patchiness of phytoplankton
   (c) study of the large scale meridional and zonal water transport at various depths in relation to the life cycle of krill.

2. Study of the variability between years and regions in the concentration and composition of phytoplankton.
3. Autecological studies of key organisms of the Antarctic ecosystem such as whales, seals, penguins, fishes, squids, krill, some other crustaceans, salps; assessment of their standing stocks/biomass and production in selected areas of the Southern Ocean.
4. Description of the major food chains in Antarctic waters with emphasis on the flux of energy and material between the various trophic levels in selected small areas.
5. Development of models to improve our understanding of the quantitative interaction between different elements of the ecosystem and the effects of climate, whaling and krill fishing on structure and efficiency of the food chain.
6. Compilation and analysis of data from exploratory and commercial fishing.
7. Provision of scientific information on the Antarctic ecosystem to the scientific community, governments, industries, and other concerned bodies.

# 2. RESEARCH PROGRAMMES

## 2.1. Introduction

This section of the report describes the individual lines of research which are necessary for an understanding of the dynamics of the Antarctic marine ecosystem and for the conservation of the living resources. The following sub-sections describe the proposals in respect to the main elements and processes of the system. Emphasis has been given to those elements which are believed to contribute most to the general flow of material and energy through the higher trophic levels, or are currently under exploitation or have potential for exploitation. This has inevitably meant that some elements and processes of considerable scientific interest have presently had to be neglected. So, although there is no section dealing with the benthos, this does not imply that research on benthic community structure and productivity is unimportant. Throughout the proposals, links between the benthic and pelagic communities have been emphasized. Benthic communities are important in recycling nutrients, and benthic species provide the food source for demersal fish populations. The role of benthic animals as consumers of krill also needs to be elucidated.

While an understanding of the trophodynamics of the Southern Ocean ecosystem is vital from the viewpoint of resource management and conservation, it should be stressed that we have a unique opportunity to contribute to our understanding of marine ecosystem processes as a whole. Detailed studies combined with the modelling investigations described below can lead to significant advances in our knowledge of ocean processes.

Inevitably the proposals for different stocks have developed to different levels of detail. Following the long history of whaling, research on whales and the population dynamics of whales are well advanced. Over the past few years in particular, whale scientists have been actively engaged for the International Whaling Commission (IWC) and other organizations in reviewing the status of whale research, and drawing up a comprehensive international programme of whale studies. In spite of large-scale and in-depth studies of krill there are still outstanding problems. It has, therefore, been much easier to draw up a balanced and detailed programme for whales than for krill. It must also be emphasized that the krill programme (and indeed most other elements in the BIOMASS programme) will be modified in respect to specific topics as the programme develops and our knowledge of krill increases.

## 2.2 Modelling

A whole ecosystem perspective is essential to the understanding and careful use of living resources in Antarctic waters, but it is not easy to develop this perspective from the usual starting point of observation of one particular element in the system. One method of tackling the work of understanding the whole ecosystem is the development of suitable models. They are particularly useful for ensuring a systematic approach to research and exploring the logical conclusion of certain hypotheses. Models also provide an ecologically meaningful framework for organizing, analysing, and integrating data of different types and from various sources. The power of modern computers allows highly complex situations to be handled. We already know where additional observations can be most productive. Considering such observations in an ecosystem context can provide guidance to those concerned with the management of individual resources such as whales, seals, fishes, and krill.

Two levels of modelling are appropriate for study of Antarctic waters: whole ecosystem and detailed sub-models. The development of a preliminary whole ecosystem model requires extension of our present knowledge. Additional biological data are necessary, both field data on the biomass of ecologically important elements of the system and experimental data on transfer rates. Such a model can serve to organize existing information and to point out areas where additional research is needed. At the same time, it can be flexible enough to incorporate further information in the course of its future development.

A model has been constructed of the Ross Sea ecosystem (Green, 1975) which describes the interactions of nutrients, light, ice, phytoplankton, zooplankton and larger animals. The general flow structure of this model is shown in Figure 2. For a Southern Ocean model, the main modifications needed include: (a) elements describing harvest by man, particularly of whales, krill, fish and cephalopods; (b) sub-division of certain elements (*eg*, of zooplankton into krill and other species); and possibly (c) division into various geographic zones, with some interchange between zones (*eg*, migration of whales). The Ross Sea model has been quantified, using available data and making estimates where necessary, to provide a descriptive simulation of an annual ecological cycle.

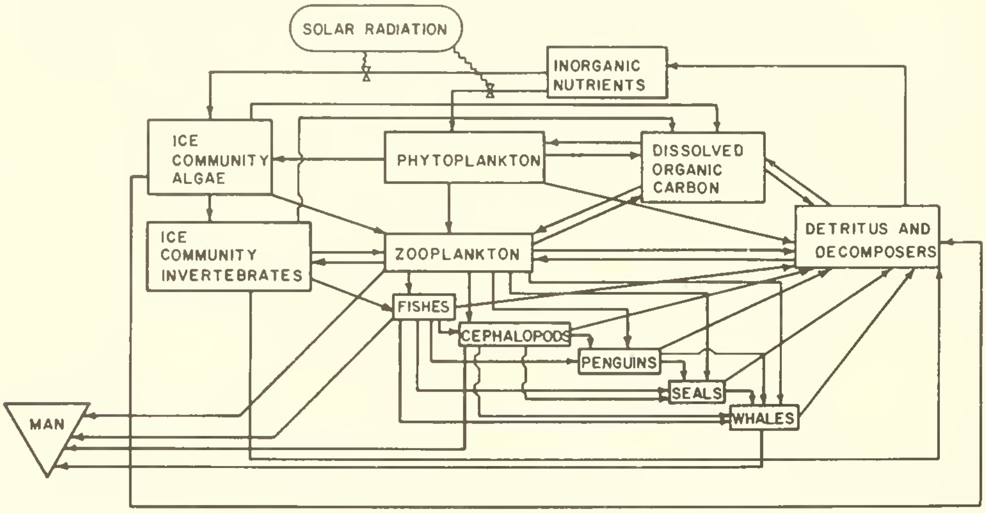

FIG 2. Conceptual model of the pelagic ecosystem of the Ross Sea; exchanges between the system and its environment are shown. (After K. A. Green, 1975.)

Construction of one model, however complex, does not offer a complete framework from which to gain an understanding of an involved system. The development of a general model of the entire system must be accompanied by other activities, such as the development of more detailed sub-models of certain elements of the system. As an example, models which deal just with the fishes and (in a simplified manner) other elements interacting directly with the fishes, can simulate gross changes in fish populations. Size and age composition of the population, individual growth rates, recruitment, and variable food consumption can be included in a fish sub-model, but it would not be practicable to do this in a general ecosystem model. Similar detailed sub-models can help explain the quantitative behaviour of single components of the total system and can be used to check on the realism of the general overall model.

The important sub-models on which work should start as soon as possible are:

(a) the physical/chemical environment as a forcing function for phytoplankton growth, with a built-in ability to allow for different sized phytoplankton to be produced under different physical/chemical conditions; and

(b) using phytoplankton as a forcing function, a krill model which includes the major predators.

At present, models are most useful for perspective, data organization, and indication of information needs. When information on such aspects as the ecological role of detritus, spatial variation in productivity, or stocks of fish and cephalopods, is more complete, then predictive capability becomes an additional objective of both whole ecosystem models and sub-models.

To make full use of the modelling process, it is necessary to bring the model builders together with those concerned with field studies, experimental studies, and general biological investigations. This will ensure that the models are useful and are indeed used to gain a better understanding of the system as a whole. There seems to be a need for modellers and other investigators to meet to exchange data, evaluate model results, refine model formulations for improved realism, and redefine information needs. A feedback process between model development and field studies will serve to develop the predictive capabilities of the various models as they are updated, validated and improved. It can also serve to identify information needs and provide some direction for future research.

At the present state of the art of ecosystem modelling, the process of model building is as useful as model results. Objectives for Antarctic models are:

1. Interaction among disciplines applied to Antarctic studies at both the conceptual and data analysis levels.
2. Focus for Antarctic research through organization of existing data and identification of information needs from an ecosystem perspective.
3. Descriptive ecology of the whole Southern Ocean at the level of interacting populations through dynamic simulation.
4. Feedback between model predictions and field and experimental research to refine both models and research programmes.
5. Ultimate development of a predictive model of Southern Ocean biology useful for conservation of Antarctic living resources.

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## 2.3 Physical, chemical and biological environments

### 2.3.1 *Review*

The broad features of the oceanography of the Southern Ocean have become well known as a result of the *Discovery* Investigations (1925–39) and the cruises of the *Ob* and the *Eltanin* in the late 1950's and 1960's. The knowledge accumulated from Antarctic investigations has shown that the physical/chemical settings of the Antarctic seas are unique in the world ocean. Their unique features are represented by: (a) the presence of pack ice around the Antarctic continent and the seasonal waxing and waning of the pack ice zone; (b) the variability of the light regime which alternates between complete perpetual darkness in winter to continuous daylight during summer; (c) the nearly uniform sea temperature which varies little with depth or season; (d) the extensive cloud cover; and (e) the circumpolarity of the surface waters and the dominant influence of the circumpolar fronts (El-Sayed and Green, 1974). It is in response to the physical/chemical environments that the Antarctic organisms have developed their characteristic features. For example, the marked seasonal variations in incoming solar radiation have a pronounced effect on plant and animal life: the rise and fall of primary production in the circum-Antarctic waters appears to be a direct response to the amount of energy received (El-Sayed, 1971).

More is known about large scale surface discontinuities such as the polar front (or Antarctic Convergence) and Antarctic Divergence than about small scale discontinuities. The fact that most species appear to have a circumpolar distribution and that those south of the polar front are distinct from those to the north suggests that the biogeography of the Southern Ocean is governed largely by the dynamics of ocean circulation.

The general pattern of ice cover, arrangement of water masses, distribution of currents, water column structure and nutrient salts regime are known, and it is clear from recent work that there is great variability in these parameters, both seasonally and from year to year, than had previously been thought. The extent of ice cover in the Southern Ocean varies with the season and is influenced by wind; the production of cold dense bottom water may be sporadic; there is considerable variation in currents and mass transport within the West Wind Drift; a well defined clockwise eddy exists in the Weddell Sea; primary production and krill abundance vary considerably from region to region, and so on.

This newly appreciated variability is currently the focus of great interest by the physical oceanographers and meteorologists participating in the ISOS programme (International Southern Ocean Studies). In the BIOMASS programme there is a need for independent research programmes in physical/chemical oceanography, and for conducting a systematic series of environmental studies on the physics, chemistry and biology of the Southern Ocean that is oriented primarily towards an understanding of the Antarctic marine ecosystem. These environmental studies will need to be closely coupled to studies of the living resources and closely co-ordinated from one ship to another and from ship to shore to satellite.

Measurements by current profilers and moored current meters, as well as frequent STD casts, should provide information on vertical transport and stability and on advection. A knowledge, from sampling, of the spatial distribution and density of krill swarms in relation to the abundance and size spectra of phytoplankton, should further our understanding of the reactions of a krill swarm to its food base and the effects of grazing on the phytoplankton. Besides quantitative sampling for krill within and outside swarms, biological observations should include controlled, quantitative plankton sampling for analyses of phytoplankton and zooplankton abundance and composition in different depth layers and at different times of day and night. Recordings of vertical distribution of chlorophyll and detritus provide additional information on the biotic environment of krill. These studies should be carried out at several selected places, mainly in different areas of high krill concentrations at the ice edge, in the neritic zone of the Antarctic Peninsula and of the Antarctic islands, as well as in the open ocean of the West Wind Drift, the East Wind Drift and the upwelling zones. If possible they should be repeated at different seasons.

### 2.3.2 *Objectives*

The objectives of this section are to provide relevant information on the physical/chemical components of the marine ecosystem in the Southern Ocean as they affect the living resources and, in particular, to:

1. Describe the physical/chemical factors governing the distribution, abundance, productivity and behaviour of the marine organisms.
2. Describe the short and long term environmental fluctuations governing the biology of Antarctic marine flora and fauna.
3. Identify and measure, for the purpose of ecosystem modelling, the main physical and chemical driving forces in oceanic and coastal areas of the Southern Ocean.

### 2.3.3 *Research programmes*

1. Factors affecting primary production.

Current estimates of primary production vary widely and our estimates are largely based on station data taken by oceanographic ships at different times and often in different years. If we are to provide reliable estimates of productivity and rates of energy flow, we must achieve geographic coverage using standardized methods and techniques.

The primary production component of the BIOMASS programme will focus on a detailed documentation of the geographic variability in rates of primary productivity and on the factors which control production in the Southern Ocean. Although the productivity in polar seas with intermittent ice cover has been thought to be limited primarily by the seasonal deficiency of available light and lack of permanent thermocline formation, recent evidence from the Arctic/sub-Arctic regions (Apollonio, 1961; McRoy and Goering, 1974) and the Antarctic (Bunt and Lee, 1970; Meguro, 1962) indicates that the ice cover in these regions provides oceanographic conditions which in fact support high primary productivity on the under-surface of the ice during periods of the year when the water column itself is not productive. This ice mantle must, therefore, play a major role in organic production in the polar seas; and the fact that photosynthesis takes place beneath ice at low light intensities becomes of special interest.

Because wind-induced turbulence carries phytoplankton down as far as the pycnocline, the amount of light available for photosynthesis varies with the depth of the mixed layer. Thus, a considerable amount of work will have to be devoted to the study of the factors that govern primary production in the Southern Ocean. Such study should include measurement of solar radiation, light penetration in the water column, vertical stability of the surface layer, and a suite of physical, chemical and biological parameters which influence these major variables (cloud type and cover, wind velocity and direction, transparency, organic and inorganic suspended matter, trace elements, vitamins, etc).

The broad features of the phytoplankton programme are outlined below:

(a) Study of the geographic and seasonal distribution of phytoplankton and estimate of primary productivity within and below the euphotic zone. Special attention needs to be given to measurements of photosynthetic activity of the micro-algae beneath the pack ice. Contributions of the various primary producer communities (pelagic, seasonal pack ice, and near-shore benthic communities–including macro-algae) should be obtained on a seasonal basis.

(b) Study of the distribution and abundance of the phytoplankton in relation to physical/chemical and biological characteristics of the water masses.

(c) Study of the effect of low temperature on metabolic rates of phytoplankton, and determination of their specific growth rates.

(d) Study of rate limiting processes, uptake kinetics of nitrogen and silica by organisms, and the specific role of zooplankton and *in situ* microbial regeneration.

(e) Study of the species composition of phytoplankton.

(f) Study of the grazing and dispersion loss rates (including loss rates to the benthos).

2. Detrital regime.

There is danger in any resource-oriented research in which studies are weighted more toward the mechanisms of production than toward the equally important mechanisms of recycling the organic material produced. The main source of detritus in the open ocean is dead plankton, faecal material, and organisms embedded in the ice. It is likely that the flux of energy through these pathways is considerable. The routine detrital programme consists of measurements of particulate organic carbon which, in combination with measures of chlorophyll *a* (for phytobiomass) and adenosine triphosphate ATP (for living matter), allow the concentration of detritus to be determined. More complex studies include measurements of transfer rates, such as rates of release of ice detritus (by melting), rates of advection from regions of high and low detritus, rates of detrital fall out, and so on. Research on associated transfer rates, such as decomposition and mineralization, was mentioned in (1) above.

3. Factors affecting secondary production.

The secondary production component of BIOMASS is focused on those elements and processes within the krill ecosystem which control or modify the flux of energy to krill. For example, part of the detrital flux may sustain significant secondary production by bacteria; other zooplankton herbivores may compete with krill for algal food; zooplankton carnivores may take developmental stages of krill in significant numbers; other zooplankton may provide alternative or supplementary forage for typical krill feeders such as some birds, seals and baleen whales. The programme should include:

(a) Study of the distribution and abundance of the zooplankton species in relation to environmental gradients and to seasonal variabilities.

(b) Study of the vertical distribution of the zooplankton in relation to the water masses and to the polar front.

(c) Study of the role of the zooplankton in the dynamics of the pelagic food webs, including the pack ice where possible.

(d) Study of the life history of key species of zooplankton with particular emphasis on their feeding biology.

So far as possible, the secondary production programme will have a size specific basis, *eg*, size specific distribution of biomass, size specific grazing and size specific respiration rates. The role of zooplankton as forage organisms for fishes, cephalopods, birds and mammals could best be studied on board those trawlers associated with BIOMASS and at shore laboratories. Recent developments in radioactive tracer technique have made it possible to investigate food relationships within the zooplankton more effectively than in the past and such studies could well constitute a major part of research programmes on ships with well equipped biological laboratories.

Because the distribution of krill corresponds, in general, with the area that is seasonally covered by pack ice, this ice-mantle is of considerable significance in the study of krill. Thus, an effective biological study of the Southern Ocean will require a fresh look at the secondary production within the pack ice ecosystem.

4. Distribution and significance of surface currents and fronts.

Because of previously established macro-scale correlation between the biology of the Southern Ocean and its major frontal zones and because the distribution of krill is so patchy, the research programme on surface physical discontinuities is an important part of the BIOMASS programme. Such studies have an advantage in that they may be carried out not only by research vessels with station time at their disposal but also by supply vessels and by remote sensing from satellites. The shipboard programme mainly includes measurements of temperature, salinity, and water transparency with occasional nutrient analyses at interesting discontinuities. The emphasis is on continuity of observations along meridional (or near-meridional) sections.

5. Structure of the water column.

The success of the krill fishery depends upon knowledge of the distribution of krill in the water column. Although empirical information is available from acoustic records, it will eventually be necessary to understand the vertical migration of krill and, in particular, the relationship between krill swarms and discontinuities in the water column. The major discontinuity at the ice edge is the shallow halocline resulting from the melting of the ice, and this should be studied. However, other discontinuities exist within the vertical range of krill, and these should also be investigated. If possible, it would be desirable to track the seasonal development and decay of these discontinuities.

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## 2.4 Krill

### 2.4.1 *Introduction*

It has been well known for many years that vast quantities of krill exist in Antarctic waters, but interest in their commercial exploitation did not arise until the early 1960's. Baleen whale stocks had declined as a consequence of overharvesting, which meant that grazing pressure on krill by these consumers was reduced. During the same period, stocks of more familiar aquatic species, taken in traditional fishing grounds, were becoming fully exploited. Reduced opportunities for increasing harvest from other areas has focused attention on the potential of other food sources and, in particular, on Antarctic krill.

Many computations have been made of production and standing stock of this pelagic euphausiid (McQuillan, 1962: Shevtsov, 1963: Jonsgard and Ruud, 1964; Mackintosh, 1966, 1970; Lyubimova and others, 1973; Omura, 1973; Fischer, 1974; Tomo and Marschoff, 1974; Everson, 1976) and most estimates of an annual harvestable yield range from 100 to 150 million tons. These figures have been derived using a variety of approaches including the consumption of past and present stocks of whales (based on their residence time in Antarctic waters, volume of stomach contents and energy requirements), consumption by other vertebrate predation, catch rates of krill in plankton nets and the proportion of primary production that is converted into krill. However, there are no direct or accurate data on the magnitude of either the standing stock or annual production of *Euphausia superba.* (Although *E. superba* is often considered to be synonymous with krill, and indeed is the dominant species, a number of other euphausiids should also be included under the term, and these are particularly important at the ice edge.)

PLATE 1. Krill *Euphausia superba.*

The estimated high productivity of krill has led some nations to engage in serious efforts to test its possibilities as a food source for animal and human populations. The USSR is reported to have taken some 20 000 tons in 1974, while Japan collected about 650 tons. Results of biochemical analyses and nutritional studies have encouraged commercial utilization and other nations—the Federal Republic of Germany, Poland, Norway, the United Kingdom—are also investigating potential krill fisheries. Recent results suggest that progress has been made towards reducing the problems of locating and catching krill, and that large catches could be taken at moderate cost, provided the fishing does not have to be interrupted to handle and process the catch. However, these latter processes still present formidable problems.

Studies on a number of biological characteristics, population distribution, swarm characteristics and position of krill in the Antarctic marine ecosystem have largely been conducted during the past six decades by, among others, the United Kingdom, Norway, USSR, and Japan. While considerable information now exists concerning biological parameters, including larval stages and distribution, sexual maturity, spawning, feeding characteristics and regional differences in population densities (Bargmann, 1937, 1945; Fraser, 1937; Marr, 1962; Mackintosh, 1966, 1972, 1973; Ivanov, 1970), there is little reliable direct data on krill growth rate, or growth increment and moult frequencies. Estimates concerning growth have been derived inferentially through extensive studies of class sizes, increases in mean class size with season, developmental phases (larval, adolescent, maturing and breeding adults) and their distributions with time. The time scale from the first calyptopis to young adolescent stages seems to be established while diverse interpretations have been made from the data of post larval size frequency distribution. Mean values of krill sizes and gonadal development, derived from numerous samples collected during about 10 years and mainly between 20°E and 70°W, have led to the conclusion that *E. superba* matures and breeds two summers after being spawned (Bargmann, 1945; Marr, 1962). However, samples collected in the vicinity of the island groups in the Scotia Sea in one season (February–April 1968) have been interpreted by some to demonstrate a four-year life cycle (Ivanov, 1970).

With continuing efforts to determine the life span of this species, Mackintosh (1972) re-evaluated earlier data, and with additional *Discovery* samples reiterated previous estimates of a two-plus-year period to breeding. Thus, critical aspects of the biology and ecology of krill remain to be clarified. These include: growth rates, longevity, fecundity; hydrographic features of areas of high as well as low population densities and transport of early larval stages; pairing and repeat spawning. These features of krill biology must be elucidated at diverse geographic locations during every season and several annual cycles. The information derived will provide the scientific basis for judgements concerning harvestable limits.

Changes in the abundance of krill is another aspect in which full information is lacking. Though our present indirect methods have produced estimates of abundance or production which may be adequate for purposes of harvesting, the variance in these estimates (considered by some to be a factor of two or so) is so great that it is impossible to estimate the changes in the abundance of krill which have occurred or may occur. While it is popularly believed that krill stocks increased after whale stocks decreased, and there is indirect evidence that this occurred. (*eg*, from increases in the populations of winged birds, penguins and seals that feed on krill (Budd and Downes, 1969; Conroy, 1974)), direct evidence is lacking. Present techniques of directly estimating krill biomass, from plankton net hauls, or by acoustic methods, are subject to considerable variance because of the structure and highly irregular distribution of the swarms. Such estimates may also be biased because, for example, of the escape of larger krill from most nets, the fully unknown proportion of krill outside swarms and the lack of information on the acoustic properties of krill, either individually or in swarms.

Though these problems are of some significance, they do not invalidate present estimates of biomass and productivity which have been presented as broad ranges. They do make it difficult or impossible, however, to achieve the precision needed to monitor changes in the krill population which might occur as a result either of a recovery of the whale stocks or of large scale exploitation. The development of methods of monitoring changes in krill abundance is highly desirable. Techniques that are under investigation and at the present stage show some promise include refined acoustic methods from ships or buoys, aerial surveys and the use of satellites.

### 2.4.2 *Objectives*

Because of its key position in the Antarctic ecosystem and the possibility of krill making a significant contribution to world food supply at some time in the future, the studies of krill proposed here have a significant part in the whole BIOMASS programme. It is planned that these studies will lead to a better understanding of: (a) the fundamental biology of *E. superba*; (b) the extent of dependence of higher trophic levels on krill stocks; (c) the interrelations between krill swarming and the hydrographic features of Antarctic waters. The studies have been drawn up so that in addition to improving our general store of scientific knowledge, sufficient information will be available before any intensive exploitation of krill begins. If these objectives are successful it should be possible to make use of the large krill resource without risk of lasting damage to stocks, or to stocks of mammals, birds and other animals which depend to a greater or lesser extent on krill for food.

In particular the objectives of the programme will be to:

1. Make an intensive study of the life history and population dynamics of krill.
2. Elucidate the contribution of krill to the dynamics of its main predators.
3. Develop systems to monitor changes in the abundance and composition of the krill stocks.

### 2.4.3 *Research programmes*

It would not be possible, given the scales of the problems and the magnitude of the resources that are likely to become available for the BIOMASS programme, to draw up practicable proposals that would deal with all the objectives of the krill research programme in the near future. The present proposals, therefore, have been selected to deal with topics that are particularly important in themselves or lay the groundwork for later important investigations. The specific proposals are:

1. Determine growth rate and longevity using (a) laboratory and field experiments, and (b) collection and analysis of length composition data for krill collected in all seasons and areas.
2. Describe the spatial distribution of krill with the objectives of determining ranges of biomass densities and the shape, extent and stability of swarms, especially diel changes.
3. Develop acoustic techniques for the quantitative survey and evaluation of krill stock.
4. Carry out surveys with quantitative nets (RMT, Bongo, etc) to determine the vertical and horizontal distribution of krill in oceanic areas, coastal areas and the pack ice zone.
5. Determine the types of fishing effort data (*eg*, number of hauls, searching time) from which a catch per unit effort could be produced to provide the most valid index of abundance, and ensure that such data are collected from any commercial krill fishing operations.
6. Carry out ecological studies throughout the Southern Ocean, with particular emphasis on the Weddell sector, in the most likely areas of potential intensive exploitation and in the important but poorly understood area of the East Weddell Drift.
7. Identify stocks or racial differences in all study areas. If sub-groups are discovered, conservation measures and management of commercial harvesting will be expected to reflect growth characteristics of such groups.
8. Study the distributions, vertical and horizontal transport of early larvae (eggs to first calyptopis stage).

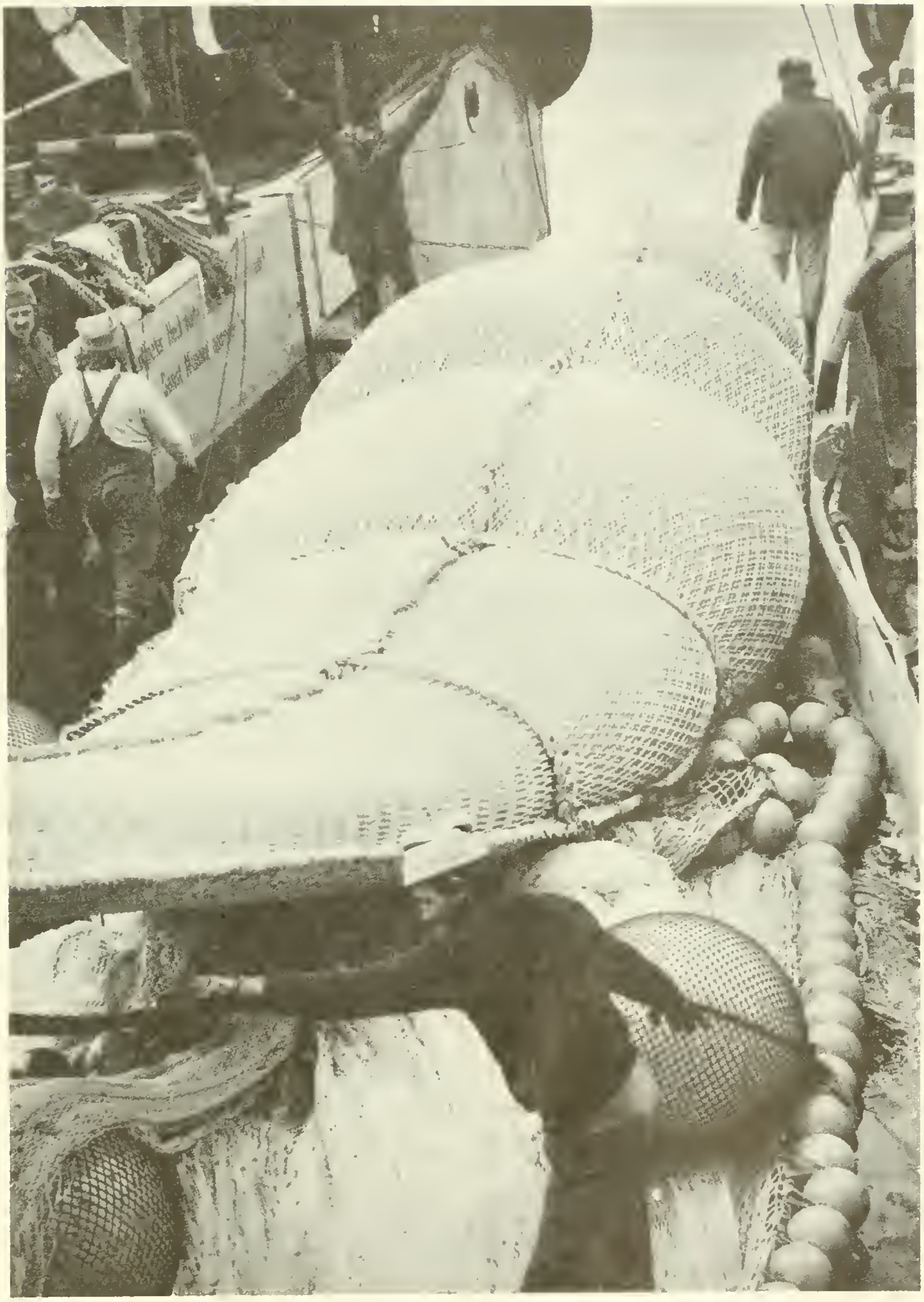

**PLATE 2.** A 25-ton catch of krill being hauled onto the deck of FFS *Walther Herwig*.

9. Investigate the biochemical composition of krill and its relation to feeding, season and growth.
10. Investigate the spawning behaviour, area, depth and intensity, and the possible occurrence of repeated spawning.
11. Evaluate the possibility of using remote-sensing techniques for monitoring krill.

In addition it will be important to ensure that comprehensive catch and effort statistics are collected and reported to the appropriate international agency.

The handling of practical fishery information can be considered as the responsibility of fishery institutes and agencies. The information is often needed to achieve the best productive tactics for the development and utilization of krill, but if large exploitation starts it will also be invaluable for quantitative studies of krill dynamics.

During the Woods Hole conference, it was possible to examine acoustic techniques in some detail. While the commercial fishing expeditions have clearly demonstrated the efficiency of hydro-acoustic techniques in detecting swarms of krill, the translation of such signals into absolute units requires special study. It was proposed to conduct as soon as possible a small scale study for the purpose of:

(a) determining the back scattering strength of various densities of krill by cage experiments

(b) providing a calibration coefficient from simultaneous fishing and hydro-acoustic mapping

(c) determining the variance encountered in different survey strategies.

To implement these proposals close international co-operation will be needed. Useful co-operation has already developed during recent years between scientists of several countries engaged in krill research and related aspects; it ranges from exchange of information such as cruise plans, preliminary results and publications, to joint participation on board research vessels during krill surveys. The existing international collaboration in krill research should be further expanded and intensified. It is essential that the methods of sampling, recording and reporting be standardized or intercalibrated as far as possible, in order to avoid the collection of material which might turn out later to be incomparable. Working groups on methods of krill research should be established to consider all items requiring standardization (*eg*, length measurements, maturity stages, stomach filling), and to elaborate proposals for survey techniques, data collection, evaluation and reporting. The recent establishment of SCOR Working Group 52 on the estimation of micronekton abundance is a first step in this direction.

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## 2.5 Marine mammals and birds

### 2.5.1 *Introduction*

The two groups of marine mammals to be found in the Southern Ocean are the seals and whales. Both represent substantial potential sources of food: the seal stocks are, and the whales were vastly more important than their Northern Hemisphere counterparts in terms of number and biomass. While there are no autochthonous peoples engaged in hunting in the south as there are in the north, it is well known that the stocks of large whales have been commercially overfished in the Southern Ocean since 1904, and with the exception of the Minke Whale are still very low compared with their former abundance.

There is a need for proper conservation and management and a growing awareness of the complex interactions between seals and whales involving possible competition for food with each other and with birds, fishes and squids. Two international conventions are concerned with the marine mammals: the International Whaling Convention, dating from 1931, and the Convention for the Conservation of Antarctic Seals, signed in 1972 but not yet in force. The SCAR Group of Specialists on Seals and the Subcommittee on Bird Biology of the SCAR Working Group on Biology are also active in this field. Adequate conservation and management depends on a continuing input of data and information.

### 2.5.2 *Ecology and abundance*

#### 1. Seals

The pack ice region around Antarctica is the habitat of the Antarctic seals. These are the Crabeater Seal *Lobodon carcinophagus*, the Weddell Seal *Leptonychotes weddelli*, the Leopard Seal *Hydrurga leptonyx*, and the Ross Seal *Ommatophoca rossi*. These species have recently drawn considerable worldwide attention since they are a resource as yet unexploited by man. Other seal species which inhabit the Southern Ocean are the Southern Elephant Seal *Mirounga leonina* and the Fur Seals *Arctocephalus gazella* and *A. tropicalis*. These species were overexploited by the 18th and 19th century sealers and the stocks are still recovering.

TABLE 1. CRUDE ESTIMATES OF ANTARCTIC SEAL POPULATIONS, BIOMASS AND FOOD CONSUMPTION

| Species | Stock (thousands) | Mean weight (kg) | Population biomass[1] | Annual food consumption[1] | | | |
|---|---|---|---|---|---|---|---|
| | | | | total | krill | squids | fishes |
| Elephant | 600 | 500 | 300 | 6 000 | – | 3 000[2] | 3 000[2] |
| Leopard | 220 | 272 | 60 | 1 403 | 519 | 112 | 182 |
| Weddell | 730 | 246 | 180 | 4 211 | – | 463 | 2 232 |
| Crabeater | 15 000 | 193 | 3 000 | 67 245 | 63 210 | 1 345 | 2 017 |
| Ross | 220 | 173 | 38 | 892 | 80 | 571 | 196 |
| Fur | 350 | 50 | 17.5 | 410 | 205 | 102 | 102 |
| TOTAL[3] | 17 000 | – | 3 600 | 80 000 | 64 000 | 6 000 | 8 000 |

[1] Thousands of metric tons.

[2] Assumed proportions in absence of pelagic data.

[3] Totals rounded.

Scientific studies on Antarctic seals began in the early 1900's. Most of the work since has been carried out from icebreaker support vessels or in close association with the Antarctic shore stations. In general, the Crabeater, Leopard and Ross seals are distributed in the pack ice regions surrounding the Antarctic continent. Erickson and Hofman (1974) have provided maps which summarize information on distribution and abundance of these species based on census information from the years 1968 and 1974. Estimates of the abundance of various species in these regions are presented in Table 1. For the pack ice species the estimates have been corrected for variation which might occur in surface counts due to the seals' 24-hour activity pattern, but they are, nevertheless, underestimates because an unknown proportion is in the water even at peak haul out times.

RESEARCH PROGRAMMES

(a) Crabeater Seal.

The Crabeater Seal is the most abundant seal in the Antarctic and probably in the world. Siniff and others (1970) and Erickson and others (1971) have shown a relationship between ice type, in terms of cover and density, and Crabeater Seal abundance. The largest numbers of Crabeater Seals are to be found in small ice floe environments covering between 30 and 70 per cent of the water surface. The Crabeater Seal has a 24-hour activity pattern with peak numbers hauled out, it is thought, at local apparent noon; research is needed to document what the proportion may be. The food of the Crabeater Seal is mainly krill, mostly *Euphausia superba,* though there is a possibility that the bulk of the food will be *E. crystallorophias* in some areas over the shelf.

PLATE 3. A Crabeater Seal family group.

Little is known about the breeding of the Crabeater Seal since it occurs in the austral spring when the ice is at its maximum (Laws, 1958; Øritsland, 1970). After weaning, the pups probably disperse and form groups in the pack ice. Hofman (1975), Lindsey (1937) and Bertram (1940) suggest that the young of the year congregate along the edge of the Antarctic continent in areas where the ice is quite dense. This leads to a segregation by sex and age, the older, mature animals being at the periphery of the pack ice with the younger animals toward the interior (Hofman, 1975). The maximum recorded age for a Crabeater Seal is 33 years. Little is known about mortality, although the Killer Whale and Leopard Seal are known to feed on this species. Predation would appear to be significant since a high proportion of Crabeater Seals observed in the pack ice are scarred.

(b) Leopard Seal.

The Leopard Seal is the largest of the true Antarctic seals. It appears that it is catholic in its diet and takes penguins under rather specific conditions but utilizes krill, fish and other seals, particularly young Crabeater Seals, when conditions are favourable.

Little is known about the life cycle of the Leopard Seal. Pupping and mating probably occur in the pack ice. Øritsland (1970) reported that males and females become sexually mature between three and six years with the maximum life span in the vicinity of 25 years.

(c) Ross Seal.

Information on the Ross Seal, known as the rarest and least studied of the Antarctic seals, has been summarized by Hofman and others (1973). It appears mainly to inhabit pack ice of 5/10–7/10 cover. Most sightings have been of solitary individuals but groups of up to 13 have been sighted (Laws, 1964). The Ross Seal is extremely rare in the Weddell Sea but its distribution is uneven: much higher concentrations are found in the Amundsen, Bellingshausen and King Haakon VII seas. It is considered to account for between one and two per cent of the total Antarctic pinniped population.

Cephalopods have been reported to be the main food of the Ross Seal although both fish and krill have been found in its stomachs. Information on reproduction is limited, most coming from Øritsland (1970) who examined 15 specimens. It appears that pupping and mating occur in November and December.

(d) Weddell Seal.

The Weddell Seal is the best known of the Antarctic seal species as it is found near Antarctic shore stations where access for study has been possible. It aggregates during the pupping season along perennial tide cracks where pups are born on the surface of the ice. Pupping occurs as early as September in northern areas and in late October and early November in the more southern areas. Weaning is usually accomplished by the sixth or seventh week, at which time the colony disperses.

The males occupy underwater territories (D. B. Siniff, unpublished ms) along the tide crack; the exact time of mating is uncertain but it appears to be near weaning. As with the other Antarctic seals, peak haul out is around local apparent noon. Their food includes fish, crustaceans (including euphausiids), and cephalopods (Dearborn, 1965). At McMurdo Station the Weddell Seal feeds on fish of the genus *Trematomus* and midwater species such as *Pleuragramma antarcticum.*

(e) Fur Seals.

Although formerly hunted to near extinction, there is at present no harvest of these species and the populations are increasing.

The Fur Seal that breeds on islands south of the Antarctic Convergence is *Arctocephalus gazella* (Repenning and others, 1971). The main population of *A. gazella* is found on South Georgia. It has increased from at most a few hundred in the 1930's to around 350 000 now. Subsidiary smaller populations are found on other islands of the Scotia Arc north of 65°S, Bouvet and McDonald islands and, lately, this species has also begun breeding at Marion Island, sympatrically with the more northern form *A. tropicalis* (Bonner, 1968; Erickson and Hofman, 1974). The species may be expected to reach its former abundance, measured in millions, in 15–20 years time.

*A. tropicalis,* the Fur Seal of the islands to the north of the Antarctic Convergence, has shown a slower rate of recovery. Stocks at Marion Island have increased from around 500 to 7 000 between 1950 and the present, and at Gough Island from about 12 000 to 26 000 in the same period (P. R. Condy, personal communication).

Fur Seals come ashore to breed on rocky coasts in November and lactating females remain in the vicinity of the rookeries until the following March. For *A. gazella* food at this period appears to be mainly *Euphausia superba* (though fishes and squids are also taken). The food of *A. tropicalis* is less well known but includes fishes, squids or the rock lobster *Jasus* sp. After harem break-up the Fur Seals disperse. Their distribution and feeding habits in the winter are unknown.

(f) Southern Elephant Seal.

This species is similar to the Southern Fur Seal in that it congregates on beaches to have pups and mate. The total mid-year population has been estimated at about 600 000 with the largest population (370 000) on South Georgia (Laws, 1960). The first mature bulls establish territories in September and the breeding season lasts until mid-November. Elephant Seals do not feed during the breeding season nor during the period of moult that follows. Their primary food is cephalopods and fish, but in what proportion is not known.

Although almost exterminated at South Georgia in the 19th century, the numbers under protection were increased and the species was the subject of a successful nationally managed industry, which took only adult males from 1910 to 1964; the sustainable yield appeared to be about 6 000 (Laws, 1960).

PLATE 4. Minke Whales in Normanna Strait, South Orkney Islands.

2. Antarctic whales.

The whales include the baleen whales (*Mysticeti*) and toothed whales (*Odontoceti*). The waters surrounding the Antarctic continent are inhabited by the following five species of the large baleen whales: Blue Whale *Balaenoptera musculus*, Fin Whale *B. physalus*, Sei Whale *B. borealis*, Humpback Whale *Megaptera novaeangliae* and the Sperm Whale *Physeter catodon*, the only large odontocete. The smaller Minke Whale *Balaenoptera acutorostrata* also inhabits these waters, and the Southern Right Whale *Eubalaena australis* occasionally migrates into the

## TABLE 2. CRUDE ESTIMATES OF LARGE WHALE POPULATIONS, BIOMASS AND FOOD CONSUMPTION

| Species | Stock (thousands) | Mean weight (metric tons) | Mean Antarctic biomass[1] | Food consumption in Antarctic[1] | | | Biomass loss outside Antarctic[1] |
|---|---|---|---|---|---|---|---|
| | | | | krill | squids | fishes | |
| *Initial stocks* | | | | | | | |
| Baleen whales | | | | | | | |
| Fin | 400 | 50 | 20 000 | 81 480 | 840 | 1 680 | |
| Blue | 200 | 88 | 17 600 | 71 702 | 740 | 1 478 | |
| Sei | 75[2] | 18.5 | 1 387 | 5 651 | 58 | 116 | |
| Humpback | 100 | 27 | 2 700 | 11 000 | 113 | 227 | |
| Minke | 200 | 7 | 1 400 | 10 000[4] | 204 | 409 | |
| TOTAL | 975 | | 43 000 | 180 000 | 2 000 | 4 000 | 18 000 |
| Sperm Whale | 85[3] | 30 | 2 600 | | 10 200 | 500 | 600 |
| *Present stocks* | | | | | | | |
| Baleen whales | | | | | | | |
| Fin | 84 | 48 | 4 032 | 16 426 | 169 | 339 | |
| Blue | 10 | 83 | 830 | 3 381 | 35 | 70 | |
| Sei | 40.5[2] | 17.5 | 709 | 2 888 | 30 | 60 | |
| Humpback | 3 | 26.5 | 79 | 322 | 3 | 7 | |
| Minke | 200 | 7 | 1 400 | 10 000[4] | 204 | 409 | |
| TOTAL[5] | 338 | | 7 000 | 33 000 | 440 | 880 | 2 500 |
| Sperm Whale | 43[3] | 27 | 1 200 | | 4 600 | 250 | 250 |

[1] Thousands of metric tons.

[2] Half total Sei Whale stock assumed to feed south of the Antarctic Convergence.

[3] One third total 'exploitable male' Sperm Whales assumed to feed in the Antarctic.

[4] Minke Whale assumed to feed for six months in Antarctic waters at 4 per cent body weight/day.

[5] Totals rounded.

area although it generally remains north in the more temperate latitudes. Nine species of small odontocetes inhabit Antarctic waters, including the Killer Whale *Orcinus orca*, which may be important in predator-prey interactions within the ecosystem. Mackintosh (1965) gives a good summary of the biology of large whales. Brownell (1974) reviews existing information on the small cetacea, but our knowledge of these mammals is far from complete and they will not be further considered here.

In Table 2, data on both the initial and present stocks of large whales are presented. They represent the concensus among whale biologists and the methods by which the figures were reached are summarized by Mackintosh (1965), Laws (1977 and in press) and the annual reports of the International Whaling Commission. There is more uncertainty about the Minke Whale, which is less migratory than the other species; its food consumption has been estimated by assuming that on the average it feeds in the Antarctic for half the year. The table indicates that the initial stocks of large whales, before exploitation began, probably consumed about 180 million tons of krill, 12 million tons of squid and 4.5 million tons of fish. Their numerical abundance is now reduced to about 38 per cent of the initial population, their biomass more so, and they are estimated to consume substantially less than before; namely, 33 million tons of krill, 5 million tons of squid and about 1 million tons of fish, annually. In order to predict future trends of abundance it will be necessary to monitor the stocks for many years.

The biology of Antarctic whales follows a basic pattern: intensive feeding in Antarctic waters in the summer months when they store up an energy reserve in the form of blubber, followed by an autumn migration northwards. They feed during the winter at no more than a tenth of the summer rate and in spring they migrate southwards again to feed. It has been estimated that their body weight increases by about 50 per cent during the period of intensive feeding (the Sperm Whale to a lesser extent), and most of this is lost in the winter. The transfer of material, by metabolism, and the loss due to deaths outside Antarctic waters formerly totalled about 19 million tons and are now estimated to total only 3 million tons. While this drop is probably insignificant in relation to the whole of the Southern Ocean it may be locally important, particularly with regard to the source of nutrients in lower latitudes.

The distribution of these whales follows a circumpolar zonation with the larger species tending to penetrate into colder more southerly waters (the Minke Whale is an exception), and larger individuals within species also occupying the more southerly part of a species' range. This pattern results, together with other behavioural and morphological specializations, in a measure of ecological separation, particularly in feeding methods.

### 3. Birds.

Sea birds, particularly the penguins, albatrosses and petrels, are conspicuous members of the Antarctic and sub-Antarctic ecosystems. They constitute an integral part of the Antarctic ecosystem and exploitation of other resources could have a significant impact upon their populations and on the ecosystem as a whole. Their distribution in the Southern Ocean is zonal, the principal limits being the Antarctic coastal zone, the northern pack ice edge, the Antarctic Convergence and the sub-Tropical Convergence. Due to the circumpolar nature of these zones, many species are circumpolar in distribution. Sea birds are represented in the breeding stocks south of the sub-Tropical Convergence, in the islands and geographic areas delineated by Carrick and Ingham (1967), by eight families and 44 species (Watson and others, 1971; Barratt and Mougin, 1974).

Seven species of penguins (*Spheniscidae*) occur in the region; three of these are confined largely within the limits of the pack ice. They comprise about 87 per cent of the stocks of birds (or 90 per cent of the biomass) in the Antarctic and 53 per cent of the stocks of birds (or 83 per cent of the biomass) in the sub-Antarctic. In terms of biomass the Adélie Penguins are by far the most important birds in the pack ice. Penguins are quite easy to study at their breeding sites and thus their breeding biology has become well known. A few populations of penguins have been the subject of long term study. Most species feed principally on zooplankton, especially euphausiids, although a few concentrate their diets on fishes or squids.

The breeding albatrosses (*Diomedeidae*) include six species, most of which occur largely in the sub-Antarctic zone. Their natural history, fairly well known for some species, is characterized by a lengthy period of immaturity during which individuals circumnavigate the Antarctic perhaps more than once–one reason for their very low reproductive rates. Albatrosses apparently feed heavily on pelagic squids and zooplankton.

PLATE 5. Adélie Penguins.

The petrels (*Procellariidae*, *Hydrobatidae* and *Pelecanoididae*) are a diverse group represented by 24 species ranging in weight from 0.04 to 4.3 kg. With a few exceptions, they are the least well known of Antarctic sea birds. The migrations and subsequent deaths elsewhere of some species, for instance, the Sooty Shearwater *Puffinus griseus*, constitute a pathway by which energy is transferred out of the Antarctic ecosystem. Dietary habits within the group are diverse, the petrels' prey ranging from the tiniest zooplankton to the larger fishes, squids and carrion.

The shags (*Phalacrocoracidae*) are quite different from the penguins and petrels in that they remain close to their breeding sites throughout the year and are confined in their feeding to shelf areas around islands. Also their reproductive potential, as measured by the number of eggs laid per breeding attempt, is much greater than that of the penguins and petrels. Their breeding biology and ecology, however, are not well known. Because of their limited distribution, they are important members of the Antarctic ecosystem only in small, local areas.

The *Stercorariidae* and *Laridae*, which include five species, are well known, particularly the skuas, but their low numbers and biomass render them relatively insignificant in the ecosystem. Their primary effect, with the exception of the terns, is by their scavenging within the rookeries of seals and other sea birds.

The importance of sea birds in the Antarctic ecosystem lies largely in their role as consumers. According to more or less empirical calculations on different species, the Antarctic and sub-Antarctic regions contain at least 188 million birds with a total biomass of 577 000 tons (Table 3)[1]. 65 per cent of the stocks are distributed in the sub-Antarctic region representing 55 per cent of the total biomass. The *Spheniscidae* determined from these figures constitute 65 per cent of the stocks and 90 per cent of the biomass for the whole Antarctic region. The birds are estimated to consume 39 million tons of food per year including 21 million tons for the sub-Antarctic region (54 per cent). The *Spheniscidae* alone consume 86 per cent of the total. As consumers, birds are presently about equal in importance to the large whales and about half as important as the seals. They consume a relatively small proportion of the krill standing stock in summer when food is perhaps not a limiting factor for them; on the other hand, it is likely that winter plankton availability constitutes a major factor limiting their abundance.

TABLE 3. ESTIMATES OF ANTARCTIC BIRD POPULATIONS, BIOMASS, AND FOOD CONSUMPTION

| | Stocks (thousands) | Biomass[1] | Food consumption in Antarctic and sub-Antarctic[1] |
|---|---|---|---|
| *Spheniscidae* | 121 770 | 520.7 | 33 173 |
| *Diomedeidae* | 12 630 | 44.45 | 2 867 |
| *Procellariidae* | 39 354 | 10.17 | 2 131 |
| *Pelecanoididae* | 11 000 | 1.3 | 427 |
| *Hydrobatidae* | | | |
| *Phalcrocoracidae* | 2 835 | 0.56 | 65 |
| *Stercoraciidae* | | | |
| *Laridae* | | | |
| TOTAL[2] | 188 000 | 580 | 39 000 |

[1] Thousands of metric tons.

[2] Totals rounded.

### 2.5.3 *Interactions*

Direct interactions are thought to be limited to the predator-prey relationships exhibited by Killer Whales and Leopard Seals toward smaller marine mammals and penguins and those exhibited by skuas and gulls toward other species. Preferences of various seal species (Ross, Crabeater and Leopard) for different ice types may ease interspecific competition for space. Although Elephant and Fur seals are both land breeders, their distribution overlap is reduced by their occupying, at South Georgia for example, different habitats (sandy beaches by Elephant Seals and rocky shores by Fur Seals) and by staggered pupping seasons. It is probable that behavioural interactions in relation to food resources occur. Odontocetes tend to be gregarious while hunting and are known to communicate acoustically underwater.

Indirect interactions through competition for the common food resources such as krill and squids are considered to be more important. Despite the fact that for some groups, such as colonial birds, the major limiting factor may be availability of nest sites, there is evidence indicating that food availability is still an important factor. In terms of food consumption, birds and large whales are each estimated to take about 40 million tons annually while seals take about twice as much--80 million tons. Originally the large whales were estimated to have taken nearly 200 million tons annually of krill, squid and fish before their stocks were depleted by whaling.

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[1] Recent observations (British Antarctic Survey, 1977) at South Georgia indicate that the biomass of Macaroni Penguins *Eudyptes chrysolophus* at the north-west end of the island alone is in excess of 100 000 tons.

The staggered southerly migration of baleen whales and their feeding preferences for different class sizes of krill and other zooplankton reduce competition. However, it has been demonstrated that longitudinal segregation also occurs with the larger and older whales arriving first to occupy certain areas of the feeding grounds, and younger, later arrivals being displaced to the periphery (Laws, 1960). At South Georgia, for example, where the different species overlap, competition for krill of the same size occurs. The growth and pregnancy rates of Blue and Fin whales have increased and the mean age of sexual maturity has decreased during the periods of expanding whaling operations in response to increased food abundance (Laws, 1977 and in press). Similar increases in pregnancy rates and advancement of maturity in Sei Whales have been shown to precede large scale exploitation of the species, and so could not be a direct result of hunting. This lends support to the belief that the increased early pregnancies and growth rates are indirect responses to whaling through its effect on food supply.

There is no direct evidence of a change in abundance of krill-eating Crabeater Seals, but there is evidence of an increased rate of reproduction. Their mean age of sexual maturity in Whaling Zone 1 (the Sanctuary) has decreased from 4 years in 1955 to 2.5 in 1970 during a period of rapid depletion of whale stocks (Laws, 1977). At South Georgia the population explosion shown by the krill-feeding Fur Seal *Arctocephalus gazella* is very marked and other colonies are developing in the Scotia Arc. Their distribution overlaps the baleen whale feeding distribution and the much more rapid recovery of *A. gazella* in comparison with *A. tropicalis* can probably be attributed to changes in krill availability.

### 2.5.4 *Objectives.*

The objectives of the programme will be:

1. Identification of unit breeding or management stocks, their location, movements and possible mixing.
2. To obtain full data by species, sex, age and size for all catches.
3. Stock assessment and the estimation of potential yields when appropriate.
4. An understanding of trophodynamics.
5. An understanding of interactions between whales, seals and birds and with other groups at a similar trophic level, such as fishes and squids.
6. Formulation of suitable management and conservation procedures.

Objective 2 is being met under schemes operated by the Bureau of Whaling Statistics, and in respect to seals and birds by the Antarctic Treaty (Agreed Measures for the Conservation of Antarctic Flora and Fauna). The Convention for the Conservation of Antarctic Seals calls for reporting of catches.

### 2.5.5 *Research programmes*

1. The mapping of seasonal pack ice distribution and type is particularly important in extrapolating sample seal densities to larger areas and, again primarily for seals, in assessing the significance of residual pack ice regions in summer for the separation of stocks. (Objectives 1, 2 and 4)

2. Research should be carried out throughout the range of species including, for whales and birds, the winter period outside the Southern Ocean.

3. Observations should be made from ships, including icebreakers, and aircraft, to establish distributions, estimate densities and absolute abundance of, in particular, protected whale species such as the Blue and Humpback, seals and birds in the pack ice, and birds and whales in the open sea. Seals cannot be counted in the water and counts on the pack ice give a minimal estimate of abundance. To resolve this problem, behavioural observations in the pack ice will be necessary using the telemetry developed for studies of Weddell Seals in fast ice areas. If the age structure of the population is known, estimates of the abundance of birds, Elephant, Weddell or Fur seals, a portion of whose stocks concentrates on land or fast ice to breed, can be made by extrapolation from counts of breeding birds or seal pups. These counts can be made on the ground or from aerial photographs, but must be carried out before the breeding birds or seal pups disperse. Differential dispersal at sea by season, sex and age means that direct counts of the total population of land breeders are not possible. Information on the distribution and abundance of small whales is almost totally lacking and indirect methods such as radio- and sonic-tagging and hydrophone arrays must be employed. (Objectives 1 and 3)

4. Information from scientific research needs to be supplemented by data from whaling and sealing operations. The most direct way of evaluating estimates of sustainable yields is by using data on catches and effort to determine the effect of various levels of exploitation on the stocks. A programme of pelagic research captures from specially equipped whaling vessels such as the Norwegian *Peder Huse,* which was a combined whale catcher and factory ship, and from other vessels, including icebreakers for the seals in the pack ice, is necessary to complement and extend the results from commercial operations. (Objective 2)

5. Existing marking programmes should be continued and new ones developed, especially for smaller species. Methods should also be developed for the study of individual whales, seals and birds, possibly including satellite tracking, radiotelemetry and sonic tagging. (Objectives 1 and 3)

6. Marking/recapture data, studies of population genetics, morphometrics and other indicators of discrete populations should be used to establish unit stocks. Much can also be learned from captured seals without having to kill them—for example, by collection of blood samples for serological and reproductive studies, and of nails for age determination. (Objectives 1, 2 and 4)

7. For animals killed during commercial operations, in research operations using special ships and in shore-based work, the following basic studies are required:

(a) Morphometrics.

(b) Age determination to establish growth rates, population structure and natural mortality rates, and age-specific reproductive parameters. Good age criteria exist for a number of species from earlier studies; for example, annual layers in teeth (dentine or cement), nails or ear plugs. Because of the numerous age groups, relatively large samples will be needed.

(c) Analysis of reproductive state and reproductive history. This would include back-calculation of age at puberty of marine mammals from ear plug and tooth structure to establish possible trends in the mean age at puberty. Age-specific and time-specific pregnancy rates are also required for the mammals and, similarly, breeding success for birds.

(d) Investigation of food habits and ecological separation by species, sex and age. Preliminary studies indicate a more or less clear ecological separation in terms of geographical distribution, feeding depth stratification, adaptations for feeding (morphology, visual pigments) and food preferences. More detailed quantitative information is needed to refine existing knowledge and to establish possible seasonal and geographical differences.

(e) The development of programmes for estimating metabolic rates and energy flow. Just as biomass is a better measure than numbers for establishing the significance of a species in the ecosystem, so energetic terms are preferable to biomass, particularly in studies of interactions and competition for a possibly limiting food resource. (Objectives 1, 3, 4 and 5)

8. Analysis of the various parameters (stock sizes, growth, mortality, reproductive rates, feeding patterns) should be continued in an attempt to discover how they vary with changes in the abundance of seals, whales, birds and other groups. This will not, however, lead to early results. (Objectives 5, 6)

9. Finally, better and more dynamic ecological and trophodynamic models and population models are needed to help in the formulation of conservation and management strategies. (Objectives 4, 5 and 6)

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## 2.6 Fishes

### 2.6.1 *Introduction*

A large number of species of fish occur in the Antarctic, but most of these are small or few in numbers (Andriyashev, 1965; Dewitt, 1971; Everson, 1970; Hureau, 1970). At the present level of our understanding, Antarctic fishes do not significantly contribute to the general dynamics of the Antarctic ecosystem. Attention, therefore, has been concentrated on the following 12 species which are believed to be of major importance in the Southern Ocean (see also Figures 3, 4 and 5).

(a) *Notothenia rossii.*

Found in all coastal areas of the Scotia Arc, from South Georgia south to the Antarctic Peninsula; at Kerguelen, Crozet, Macquarie and Marion islands, and probably also at Bouvet Island. It grows to about one metre in length. The species at South Georgia spawns during April or May, and at Kerguelen at the end of May. It has probably been the most heavily exploited of Antarctic fishes. However, since the FAO statistical reporting areas combine South Georgia and the Kerguelen islands with the respective areas to the north, and because *N. rossii* is not on the list of reported species, it is combined with the 'other demersal percomorphs' category. Estimates of catches at South Georgia range from 400 tons to something in excess of 400 000 tons annually.

(b) *Champsocephalus gunnari.*

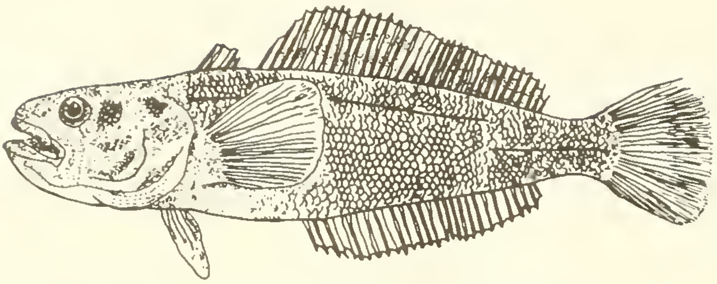
Distribution essentially the same as for *N. rossii.* The species grows to about 60 to 70 cm. Information about spawning is not available. Recent expeditions by the Federal Republic of Germany and Poland have found commercial quantities. It is one of the major species believed to have made up catches totalling 120 000 tons taken around the Kerguelen archipelago during 1971–72.

(c) *Micromesistius australis.*

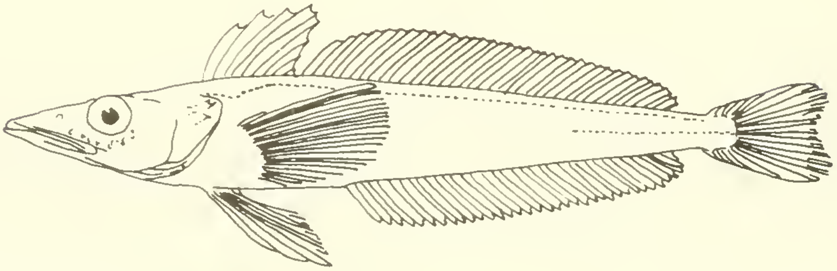
Found in the Magellanic and New Zealand regions and known to migrate south into the Antarctic Zone during the summer to feed on krill. It reaches a length of over half a metre and spawns north of the Antarctic Zone during the spring. Total annual catches up to 7 900 tons have been reported for the south-west Atlantic Ocean, which probably represent fishing efforts in the Scotia Sea.

(d) *Notothenia gibberifrons.*

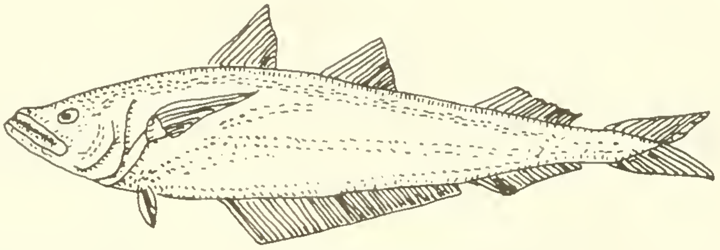
Found throughout the Scotia Arc region and off the Antarctic Peninsula. It reaches a length of about half a metre. Information about spawning is not available. Also not available are catch statistics, but the recent West German expedition took large numbers, and circumstantial evidence indicates that the USSR may be using it for at least local consumption.



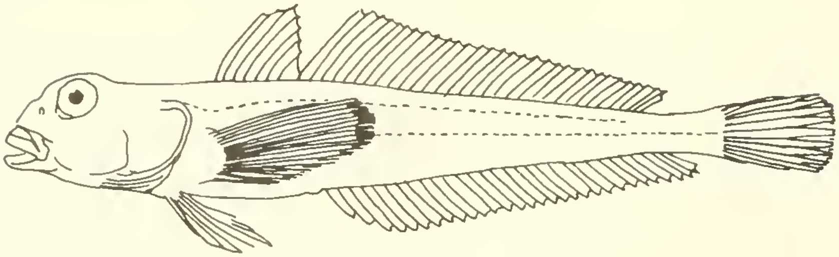
*Notothenia rossii* (length to 1 m)



*Champsocephalus gunnari* (length to 60-70 cm)



*Micromesistius australis* (length to 50 cm)



*Notothenia gibberifrons* (length to 50 cm)

FIG 3. Antarctic fishes in the order discussed in the text.

(e) *Pseudochaenichthys georgianus.*

Found at South Georgia, the South Orkney Islands and off the Antarctic Peninsula. It reaches a size of about half a metre or a little more. No information about spawning or exploitation is available except that recent West German and Polish expeditions caught significant quantities.

(f) *Dissostichus mawsoni.*

Circum-Antarctic, both in the open ocean and on the continental shelf. It reaches a size of nearly two metres and a weight of about 70 kg. The spawning season is uncertain but the species is known to have pelagic eggs. No data are available on commercial catches, but recently the West German expedition caught this species near the South Shetland Islands.

(g) *Dissostichus eleginoides.*

Found in Magellanic–South Georgia region at Kerguelen, Crozet and Marion islands. Reaches a size and weight rather smaller than *D. mawsoni.* No information about spawning or exploitation is available but may be included in the 'unspecified demersal percomorphs' category for the south-west Atlantic area.

(h) *Channichthys rhinoceratus.*

From the Kerguelen islands. Maximum length about 50 cm. No commercial catch data are available but the species is believed to have made up part of an estimated 120 000 tons taken from the Kerguelen archipelago in 1971–72.

(i) *Notothenia coriiceps* (including *N.c. coriiceps* and *N.c. neglecta*).

Found around the Antarctic continent, Scotia Arc islands except South Georgia, Kerguelen and some other sub-Antarctic islands, and probably all other Antarctic islands except Macquarie. It spawns in May, produces large demersal eggs and grows to a maximum of 50 cm in length. No commercial catch data are available, but the recent West German expedition reported catching it at the South Sandwich Islands.

(j) *Chaenocephalus aceratus.*

Found at the Scotia Arc islands and around the Antarctic Peninsula. Reaches a length of between one-half and one metre. Information regarding spawning is lacking. No commercial catch data are available, but the recent West German expedition reported this species at South Georgia.

(k) *Notothenia magellanica.*

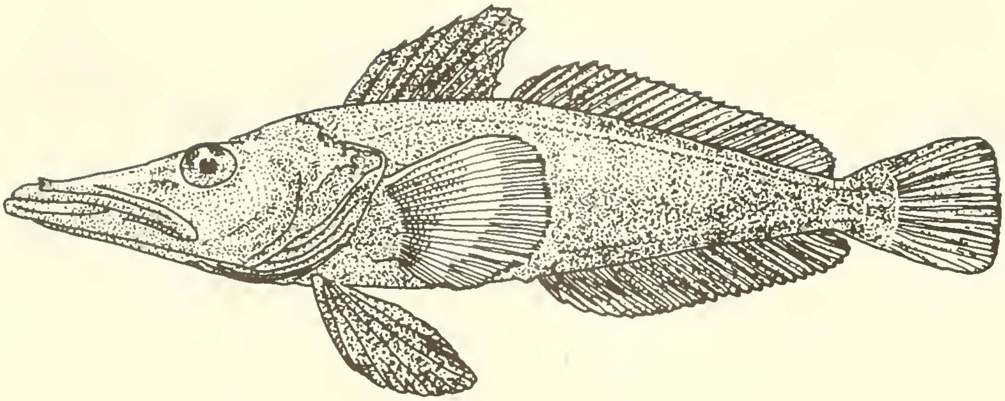
Found in Magellanic and New Zealand regions and at the islands lying on or near the Antarctic Convergence. It has been reported from the Ross and Scotia seas and may migrate there during the summer months. It reaches lengths of about 40 cm and spawns at the end of March at the Kerguelen islands; its eggs are pelagic. No commercial or other catch data are available.

(l) *Pleuragramma antarcticum.*

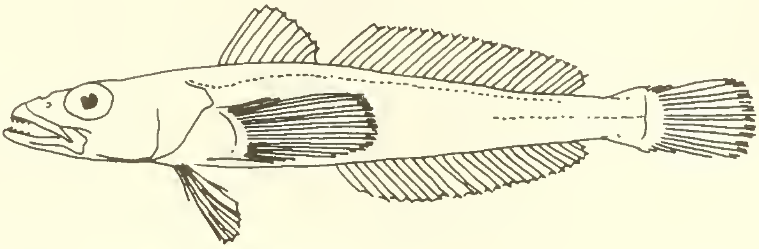
A pelagic species, circumpolar in distribution over the continental shelves. It is found as far north as the South Orkney Islands. Grows to between 20 and 30 cm. There is no information available about spawning. The fish has not been exploited.

### 2.6.2 *Objectives*

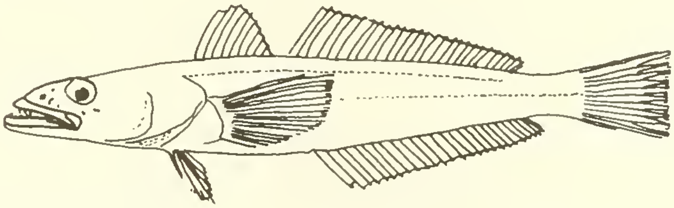
Recent investigations gave an estimate of the standing stock of fish at the Kerguelen plateau of 130 000 tons (Hureau, 1974, and in press). Data on growth of some Nototheniids are available. Nevertheless, there is still a need for more information on such aspects as distribution and standing stock of the different populations and on the growth and mortality of the individuals. Consequently, more data are needed to understand the dynamics of fish populations. Therefore, the initial objectives concerning the fish component of the BIOMASS programme will be to concentrate on the basic studies with the following general objectives:



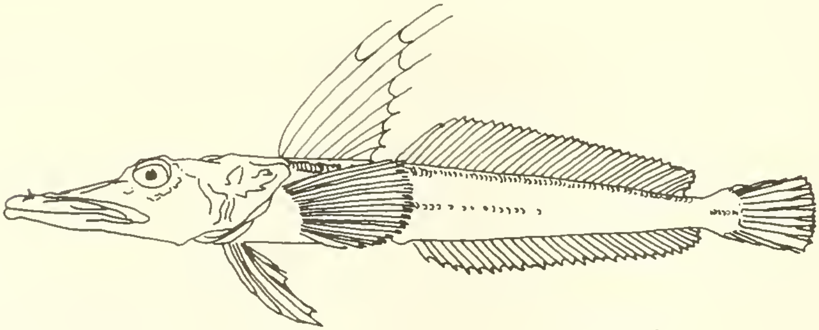
*Pseudochaenichthys georgianus* (length to 50 cm)



*Dissostichus mawsoni* (length to 2 m)

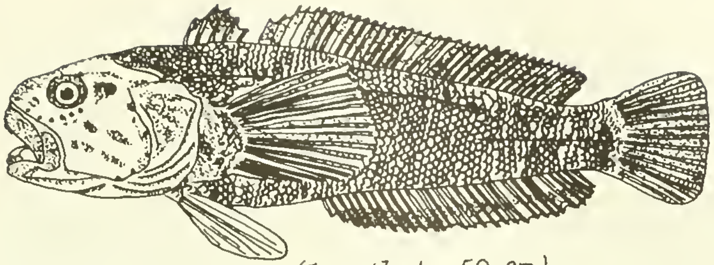


*Dissostichus eleginoides* (length to 1·3 m)

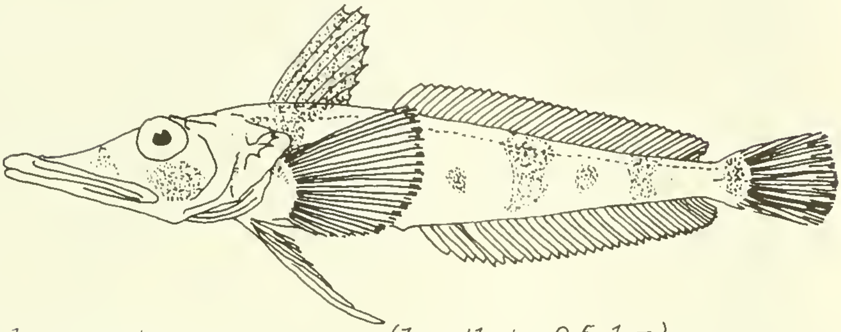


*Channichthys rhinoceratus* (length to 50 cm)

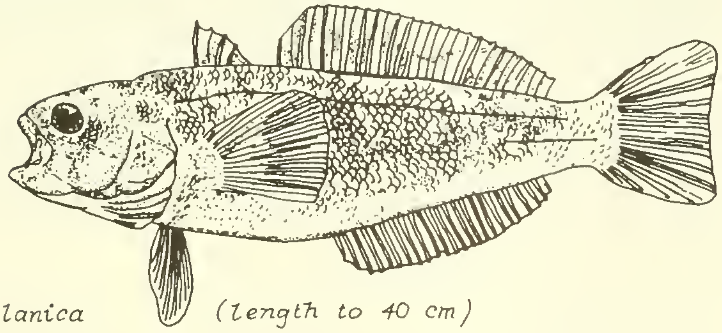
FIG 4. Antarctic fishes in the order discussed in the text.



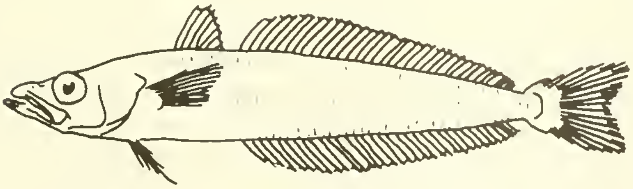
*Notothenia coriiceps* (length to 50 cm)



*Chaenocephalus aceratus* (length to 0·5-1 m)



*Notothenia magellanica* (length to 40 cm)



*Pleuragramma antarcticum* (length to 20-30 cm)

FIG 5. Antarctic fishes in the order discussed in the text.

1. Stock separation and evaluation of gross potential of fish resources.
2. Development of systems for monitoring stocks that are or may become exploited.
3. To provide estimates of population parameters for models of fish population dynamics.
4. To undertake biological studies to refine the models mentioned in Objective 3 and to improve estimates of yield.
5. To develop methods for understanding, monitoring and predicting the effects of fisheries' exploitation on other elements of the ecosystem.

### 2.6.3 *Research programmes*

The following specific programmes are proposed in order to achieve the above objectives:

1. Catch and effort statistics should be collected and inspected, a task which ought to be the responsibility of the government of any nation engaged in commercial fishing. The statistical areas should follow FAO standards.
2. Exchange programmes for age determination should be carried out.
3. Regular sampling for length (and, where possible, age) should be made from commercial catches. For this purpose, the length measurement used should be standardized, and the recording of total length, to the nearest centimetre below, is recommended. Efforts should also be made to collect information on the age structure (and failing this, size structure) of stocks of fish that have not yet been subjected to significant exploitation. This information should provide a unique opportunity for estimating natural mortality.
4. Data should be collected on the food of fishes (particularly commercial fishes) and of the principal predators, so as to quantify the predator-prey relationships which are important for trophodynamic studies.
5. Sampling of fish should be extended in areas and time as far as possible (including the use of non-commercial gear) so as to provide better information on distribution, stock separation, reproductive behaviour, possible movements and seasonal abundance. Shore stations could play an important role in this respect, and in particular morphological and electrophoretic techniques should be used. In addition, such sampling will facilitate studies of reproduction and other aspects of the life history which are important for refining population models.

## 2.7 Cephalopods

### 2.7.1 *Introduction*

Cephalopods (squids and octopuses) are known to be important organisms in the trophic structure of the Antarctic ecosystem; they constitute significant portions in the diets of Sperm Whales, seals, penguins, pelagic birds, and fishes (see Section 2.5, Tables 1 and 2). However, it is possible that they could be less abundant in the Antarctic than in the sub-Antarctic area.

The highly evolved nervous system of the cephalopods allows them to be aggressive, fast-swimming predators. This characteristic, unique among invertebrates, makes them behaviourly comparable to many large predatory vertebrates. Knowledge about their biology and, indeed, about their species composition, is almost completely lacking, due primarily to the strong swimming and net-avoidance capabilities that have prohibited adequate sampling. Therefore, one of the first steps toward elucidating the biology and resource material of cephalopods must be the development of suitable fishing gear for Antarctic conditions that can catch squids in reasonable numbers even if not in a fully quantitative manner.

Cephalopods inhabit both pelagic and benthic habitats in Southern Ocean waters. The squids are primarily pelagic forms and constitute the major resource potential in terms of numbers of species and biomass. The octopuses are primarily benthic dwellers and their biomass and consequent energy flow are relatively minor in comparison to pelagic cephalopods. This is especially the case in the Antarctic shelf waters, whereas sub-Antarctic islands appear to support larger populations of octopuses.

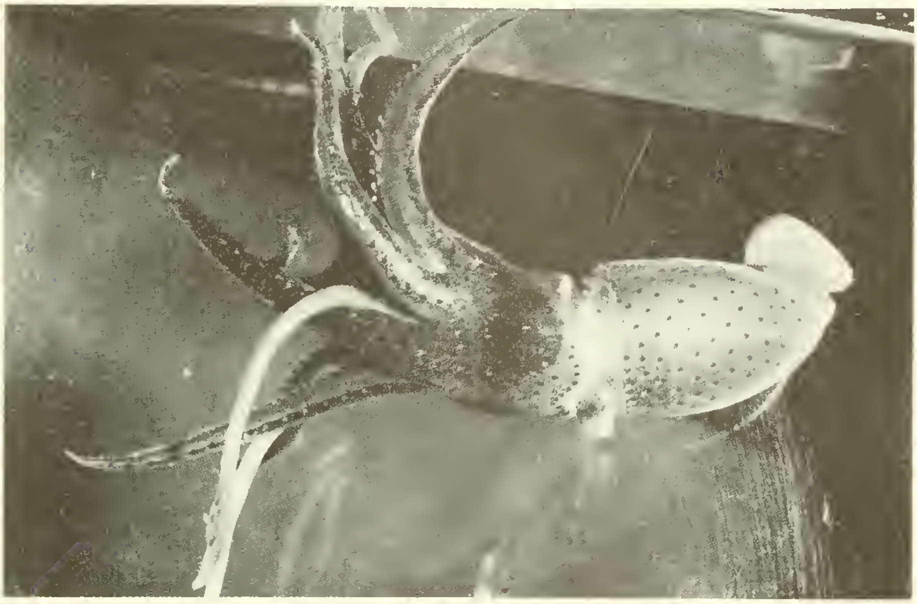


PLATE 6. A midwater squid (*Histioteuthis* sp); total length approximately 25 cm.

Currently no commercial fishery for cephalopods exists within the confines of the Southern Ocean, but an active Japanese fishery has developed in New Zealand waters for *Nototodarus sloani.* Recent statistics of this fishery are as follows:

| Year | Catch (in tons) | No of boats |
|---|---|---|
| 1972/73 | 13 423 | 71 |
| 1973/74 | 14 761 | 156 |
| 1974/75 | 18 947 | 151 |
| 1975/76 | 19 598 | 128 |

### 2.7.2 *Objectives*

The objectives of the research programme are:

1. To delineate the species composition of the Southern Ocean cephalopod fauna.
2. To conduct biological studies on species important to vertebrate predators and those potentially valuable as fisheries resources, both in relation to the size of the stocks and to predation rates. The proposed research will carry out basic biological studies based upon a comprehensive sampling programme which will utilize multiple types of biological and commercial collecting gear and include the stomach contents of cephalopod predators.

### 2.7.3 *Research programmes*

1. Biological research.

   (a) Extensive taxonomic research on Southern Ocean cephalopods is required before detailed biological studies can be made. A correct assessment of the population and subsequent decisions concerning the management of the stocks are dependent upon accurate identification of species and an understanding of the biology of each species.

   (b) Biological studies on the more important species should include distribution, vertical range, seasonal occurrence and abundance, life history, feeding strategy, reproductive potential, migrations and relationships to environmental factors.

   (c) In order to utilize fully the limited cephalopod material available, research programmes need to take advantage of every potential source of material, such as from krill trawling operations, or predators' stomach contents.

   (d) Studies should be conducted to determine the nutritional qualities of different species and even of different parts of the animals (*eg*, mantle v viscera) to assess their value to predators and to human consumers.

   (e) Research needs to be conducted, perhaps at laboratories outside the Southern Ocean area, on the behavioural responses of cephalopods to determine the effectiveness of various catching devices.

   (f) Attention should be given to rates of predation as well as to the size (biomass) of the cephalopod stocks.

2. Sampling techniques.

The paucity of knowledge about cephalopods is directly related to problems of adequate sampling. Therefore, in order to conduct basic biological studies, we propose that:

   (a) A wide variety of trawling techniques be utilized, including traditional mid-water trawls (*eg*, 3m IKMT and RMT 1&8) and large commercial trawls (*eg*, Engel's trawl), and that trawling with these large nets be conducted at depths greater than is customary for krill operations, *ie* throughout the water column and especially at the hitherto unsampled bentho-pelagic zone near the bottom.

   (b) Stomach contents from known predators (particularly Sperm Whales, seals, penguins, pelagic birds and fishes) be utilized for sampling cephalopods. A study of cephalopod beaks for identification and biomass assessment should be initiated based on material from identified cephalopod specimens. Eventually this should lead to the ability to identify beaks alone, which are so frequently found in predators' stomachs. A study of beaks and statoliths taken by deep benthic dredges should aid in assessing distributions of species.

   (c) Larval collections be conducted utilizing plankton, neuston and micronekton nets and used as an indirect means to assess cephalopod populations.

   (d) Acoustic techniques be developed for locating aggregations of cephalopods and used in association with trawling operations.

   (e) Techniques other than pelagic and benthic trawls be employed to explore alternative methods for sampling and assessing cephalopod populations, for example, large purse seines, night lighting and jigging, baited cameras, submersibles with side-scanning sonar, TV and camera-equipped sleds.

   (f) A standardized sampling protocol be established to allow comparison of results from various programmes, such as depth regime, or catch per unit effort.

(g) Net closing devices be used to ensure precision in determining vertical distributions of species.

### 2.7.4 *Implementation of research programmes*

If the objectives of the proposed research programme on cephalopods are to be achieved, full advantage must be taken of the several programmes of implementation.

Because of the unique situation of cephalopods in the Antarctic ecosystem, it is proposed that the delineation of the fauna and an understanding of its biology can be most effectively achieved by conducting a separate research project. Several ships will be equipped with standardized sampling and acoustical gear to ensure direct comparability of results. The proposed cephalopod research programmes can be conducted in collaboration and co-operation with other biological projects involved in the multi-ship programme. In addition, much valuable data can be obtained from participation in both the supporting ship-based programme and the supporting shore-based programme. In particular, co-operation with commercial trawlers and whaling factory vessels should provide specimens and data that otherwise could not be efficiently obtained.

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## 2.8 Benthic invertebrates of potential commercial importance

### 2.8.1 *Introduction*

Although research on the composition, metabolism and productivity of the benthos is needed to improve our understanding of the structure and processes of the Antarctic marine ecosystem (Mills, 1975), in this section the research programmes will be directed primarily towards those organisms which are of potential commercial importance. This, as was stated earlier (Section 2.1), does not imply that research on benthic communities is unimportant, merely that detailed study of these communities is beyond the immediate scope of this report.

For benthic invertebrate resources, the following islands were considered in addition to the shelf of the Antarctic continent:

| *Latitude* | *Islands* |
|---|---|
| 30°-40°S | St Paul and Amsterdam<br>Tristan da Cunha |
| 40°-50°S | Marion and Prince Edward<br>Crozet<br>Kerguelen<br>Antipodes<br>Bounty<br>Gough |
| 50°-60°S | Bouvet<br>Heard<br>Macquarie<br>Auckland<br>Campbell<br>South Georgia<br>South Sandwich |
| 60°-70°S | All the islands south of 60°S |

(a) Rock lobsters (spiny lobsters).

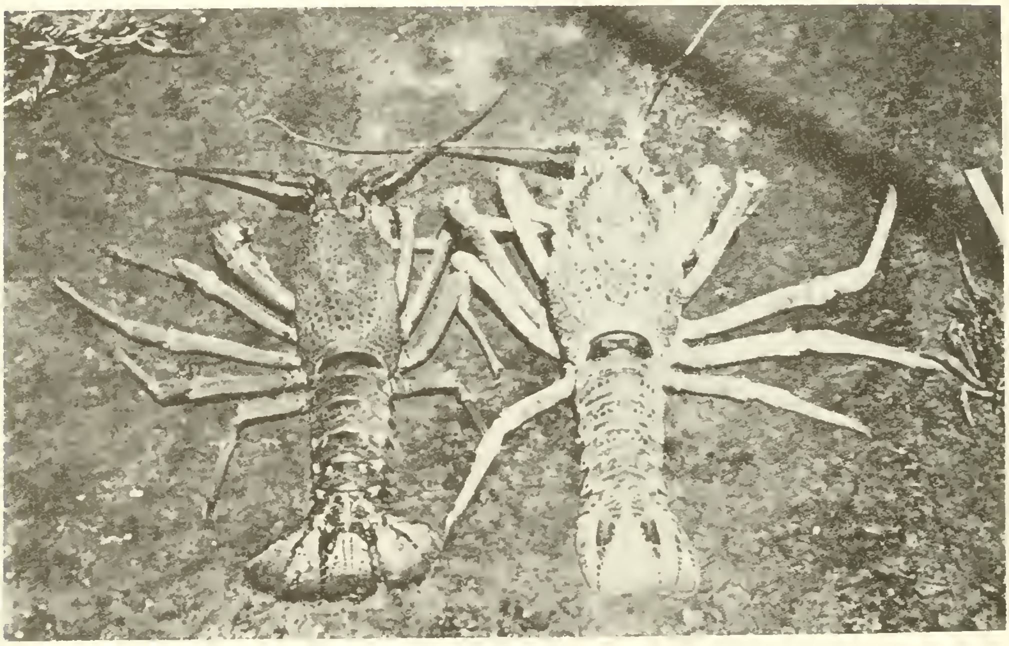

PLATE 7. Rock lobsters (*Jasus* sp).

In the Southern Ocean no benthic invertebrates are commercially harvested. However, within the wider area considered here, rock lobsters of the genus *Jasus* are currently exploited to a marked extent. At the Tristan group of islands (Tristan, Nightingale, Inaccessible, and Gough) and at Amsterdam/St Paul they have been exploited for a number of years, and for both groups of islands catch and effort statistics are available. The size composition of the catch and the production by tail size category have been recorded. Fairly good data on growth of rock lobsters at the Tristan group have been obtained from tagging experiments, which are to be continued. Analysis of size composition data has been attempted to evaluate growth rates at Amsterdam/St Paul, but the results need verification by other techniques.

Rates of tagging at Tristan and neighbouring islands have been insufficient to provide good estimates of mortality. Stock sizes and mortality have been calculated from catch per unit effort information at Amsterdam and St Paul. Estimates of stock range from 7 000 to 14 000 tons (Vranckx, 1974).

Catch per unit effort trends, as well as catch size composition, suggest that stocks are not over-exploited at Tristan and adjacent islands, and that present catch levels of about 800 metric tons nominal weight can be maintained without increasing fishing effort (Pollock, 1976). Similar analysis at Amsterdam/St Paul has indicated that stocks have declined, and the yield of 900 metric tons obtained in the past may be too high (Vranckx and Hureau, in press).

(b) Lithodid crabs.

In recent years, exploratory fishing surveys have been conducted by France to collect biological information on and to assess the potential of lithodid crabs, particularly *Lithodes murrayi*. Experimental fishing resulted in large catches around the Crozet islands. Few crabs were caught at Prince Edward Island and catches were negative at Marion and Kerguelen islands (Arnaud and Do Chi, 1976). It was felt that further surveys were required to evaluate completely the potential of these islands. In the course of the surveys, biological observations on reproduction, parasites and feeding were also made.

PLATE 8. A lithodid crab (*Lithodes murrayi*).

(c) Spider crabs.

The spider crab *Jacquinotia edwardsii* is endemic to southern New Zealand and the New Zealand sub-Antarctic (40°-50°S, 100°-165°E). It has been recorded in decreasing quantities at Pukaki Rise, Auckland Islands, Campbell Island, Bounty Islands (Anon, 1971), Stewart Island Shelf, Puysegur Bank and off the east coast of the southern South Island. The presence of large stocks in depths of less than 200 m at the Auckland Islands has also been shown (Ritchie,1970, 1973; Ryff and Voller, 1976). Experimental fishing by a joint New Zealand-Japanese expedition during the austral summer found a resource at the Pukaki Rise which was about three times that found at Auckland Islands: estimates of possible annual harvest ranged from 385 000 to 530 000 crabs (Ryff and Voller, 1976).

Apart from the stock estimates mentioned above, there is information on experimental fishing and processing, and some brief observations on moulting, reproduction, feeding and behaviour. Generally there is a paucity of information on the biology and population dynamics of this species.

(d) Other benthic invertebrates of potential commercial interest.

Other crustacean species, which have little potential value in view of their low population numbers and/or difficulty in catching are: the Antarctic shrimps (*Notocrangon antarcticus* and *Chorismus antarcticus*), other species of lithodid crabs especially *Paralomis* sp, and the smooth red swimming crab *Nectocarcinus bennetti.*

Except for the scallop *Adamussium colbecki* and the clam *Laternula elliptica*, the Antarctic shelf appears to contain few species of bivalve fauna similar to those exploited elsewhere. The sub-Antarctic islands also lack such bivalves, except for *Mytilus edulis desolationis* and *Aulacomya ater* which are abundant at Kerguelen, and *M.e. desolationis* and *A. maoriana* around the New Zealand sub-Antarctic islands.

Several other benthic invertebrate species are possibly suitable for human consumption. These include the gastropod *Neobuccinum eatoni* and sea urchins of the genus *Sterechinus.* They occur in shallow water and are generally circumpolar in distribution.

In view of the small size of the stocks and the logistic problems involved, it was concluded that the harvesting of these resources is not practical.

### 2.8.2 *Objectives*

The research programme for benthic invertebrates is to be established within the framework of the following broad objectives:

1. Assessment of the state of presently exploited stocks.
2. Identification of new resources and assessment of their magnitude.
3. Establishment of monitoring systems for exploited stocks.
4. Evaluation of biological and environmental factors which will lead to refinement of population models.

### 2.8.3 *Research programmes*

Assessment of the potential of unexploited stocks requires systematic fishing, for which the following proposals can be made.

1. Catch and effort.

The distribution of both rock lobsters and crabs is usually closely related to depth. Preliminary investigation of bathymetry, or acoustic surveys, can facilitate the systematic setting of traps and the delineation of areas of interest. A preliminary gross estimate of stock size can be made by combining catch rate with survey area and depth information.

Catch and effort statistics should be collected; these should include data on numbers, nominal weight, and production weight, as well as number of vessels, type of gear, number of traps per vessel, and number of trap days, hours or hauls. The nature of the catch and/or production should be recorded by data on size composition, state of exoskeleton, sex ratio, state of reproductive organs, and size at maturity. It is recommended that rock lobster size be expressed as carapace length, measured from the tip of the rostrum to the mid-dorsal end of the carapace, and that the size of lithodid crabs be measured from the posterior orbit to the mid-dorsal end of the carapace.

2. Growth.

This is difficult to measure in decapods. Tagging and recovery after moulting and short term holding experiments can provide good data on growth of adults. Polymodal frequency analysis can indicate growth rates of juvenile specimens.

3. Mortality.

Size composition data combined with growth information may provide rough estimates of total mortality, or natural mortality if size composition information is collected in the early stages of fishing. The rate of decline in catch per unit effort, during a short fishing season, in relation to the catch, can also provide an estimate of total mortality. The above techniques require that catchability remains constant with size and throughout the fishing season. Tagging experiments probably provide the most promising means of estimating fishing mortality. Tag loss is usually confined to the moult.

4. Yield assessments.

Trends in catch size composition and catch per unit effort reflect the impact of fishing on the stock. Better yield assessments can be made from stock production curves if a suitable time series of catch and effort data is available. If growth and mortality data are available, yield per recruit curves can be calculated to evaluate the sensitivity of the stock to changes in effort and sizes at first capture.

The above proposals refer mainly to stock assessment needs. Biological studies which would enhance population models and management should encompass the following: seasonal migrations; stock separation; feeding and predation; and larval dispersion, and recruitment.

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## 2.9 Seaweeds

### 2.9.1 *Introduction*

The littoral zones of the Antarctic and sub-Antarctic are particularly rich in benthic seaweeds. About 700 species belonging to 300 genera have been recorded from the Southern

Ocean (Délépine, 1966 and in press; Neushul, 1968; Zaneveld, 1966). There are representatives of 56 genera that have been utilized either as food or for the production of algal products in many parts of the world.

Worldwide the utilization of seaweeds is constantly increasing. Therefore, it can be expected that attention in the future will be paid to the seaweed resources of the Antarctic and sub-Antarctic. Utilization may take the form of human food, fodder for domestic animals, or the production of agricultural fertilizers, phycocolloids such as alginates, agar-agar and carrageens and medicinal products such as antibiotics.

It should be stressed that benthic marine algae are an important component of the coastal ecosystems where they contribute significantly to the overall primary production. They also provide a substantial food-source for many fishes and invertebrates, either directly or through the detritus pathway, as well as a substrate and shelter for a wide range of animal species. In addition, algae are known to excrete various substances in large quantities, but the role of these substances in the ecosystem is not yet fully determined.

Species of immediate interest in the Southern Ocean are the brown algae *Macrocystis pyrifera* and *Durvillea antarctica* and the red algae 'Agarophytes' such as the Gelidiales or Gigartinales (*Gracilaria*, *Gigartina* sp, etc). Some of the red algae are currently being exploited in South America, South Africa and New Zealand. Quantitative information has been obtained on *Macrocystis pyrifera* from the South Atlantic islands, and especially from Kerguelen, where it is estimated that the beds cover more than 200 $km^2$, with biomasses ranging from 3.4–22.5 $kg/m^2$ with means of 5–10 $kg/m^2$. On New Zealand shores the standing stock of *Durvillea antarctica* ranges from 10–20 $kg/m^2$. Standing stocks of a similar order of magnitude have been recorded from the Kerguelen islands.

### 2.9.2 *Objectives*

Research objectives are:

1. To gain an understanding of the role of benthic algae in coastal ecosystems of the Southern Ocean.
2. To carry out basic studies on the potentially exploitable benthic algal species in the Southern Ocean, and to assess the importance of this resource.

### 2.9.3 *Research programmes*

1. Stock estimation.
   - (a) Mapping of the distribution of selected species. The use of satellite imagery for this purpose should be explored.
   - (b) Estimation of standing stock and primary productivity in selected habitats. Such estimations should be carried out at different seasons and combined with estimates of total standing crops for the species studied.
   - (c) Resettlement and growth rates after clearing or harvesting in order to obtain information on the subsequent history of the cleared or harvested areas as related to the ecophysiology of the colonizing species.
   - (d) Study of the vertical distribution of the algal standing crops.
2. Ecophysiological studies.
   - (a) *In situ* (phenological studies): to include studies on growth rates, productivity, longevity, intensity of reproduction related to environmental factors such as light, photoperiodicity, temperature, etc.
   - (b) In the laboratory: studies to determine the ecophysiological reactions to environmental factors for each phase of the life cycle; life cycle studies.

3. Biochemical studies.

   Biochemical composition with season and age, including estimation for each period of the year of the quantities of different chemical constituents (nitrogen, phyllocolloids and other substances such as antibiotics).

4. General ecological studies.
   - (a) Studies of the role of algal species in the ecosystems, their utilization by consumers and their relationship to fishes and invertebrates.
   - (b) Life cycle studies both in the field and the laboratory.
   - (c) Taxonomic studies based on data from populations in the field.
   - (d) Long-term standardized measurements of environmental factors such as radiation, temperature and ice cover.

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## 2.10 Remote Sensing

### 2.10.1 *Introduction*

Remote sensing is a technique of growing importance in marine science. The remote sensing systems can take the form of devices used from aircraft, or satellite platforms, or ocean data buoys. Aircraft-borne sensors can possess different characteristics from satellite sensors. Thus, each hardware system can provide, to a large degree, different types of information; and studies and/or experiments must be designed with these different capabilities in mind.

### 2.10.2 *Objectives*

Remote sensing techniques can potentially be used to assess the abundance of phytoplankton, macro-algae, krill, birds, and mammals. The application of remote sensing is briefly reviewed in the following sections.

1. Phytoplankton.

In general there is a positive correlation between the phytoplankton standing crop (in terms of chlorophyll *a*) and primary production of surface waters; hence measurement of chlorophyll levels may be useful in assessing the productivity of these waters (El-Sayed, 1971). In recent years, there have been some pioneering studies of remote sensing of chlorophyll *a*, temperature, etc, using satellites and low flying aircraft (El-Sayed and Green, 1974). An excellent opportunity to contribute to our knowledge of using remote sensing techniques to study the standing crop of phytoplankton and other biological and physical attributes of the water column will soon be available through the use of the Coastal Zone Colour Scanner (CZCS) on the NASA NIMBUS–G satellite to be launched in 1978. It is interesting to point out in this respect that one member of the Group of Specialists (S. Z. El-Sayed) is also a member of the CZCS NIMBUS–G Experiment Team.

2. Krill.

The activity of euphausiid swarms produces a long-lasting luminescence, and will probably be detectable by Low Light Level Television. The images from such sensors may be stored on videotape for later processing. Thus, the night-time aerial/acoustic method of abundance estimation which has been developed for pilchard (Cram and Hampton, 1976) may be applicable to that part of the krill population occurring near the surface in ice-free areas where sufficient darkness can be expected.

Alternatively, if the visibility of shoals is adequate, the numerous daylight photographic and spectro-radiometric techniques reviewed by Benigno (1970) might also be highly suitable. Krill swarms have been recorded to have colour characteristics ranging from brilliant red to ochre and yellow. Such variation in colour probably indicates differing biological characteristics; hence, for successful identification with remote sensing, baseline work is needed to interpret the relationship between colour and biology of the species.

3. Birds and mammals.

This group is most visible on the surface of ice or on land but less conspicuous when swimming in the water. Each group and/or species have characteristics which make them unique when considering remote sensing applications. The penguins congregate on rookeries to breed and nest. During this time their density is high, and concentrations of over 100 000 animals are found. However, the seals of the region rarely concentrate in large numbers and are usually distributed in small groups. Exceptions are the Weddell, Elephant and Fur seals, which congregate yearly to breed.

It appears that the current instrumentation of satellites is of limited use for the direct sensing of vertebrates of the region because its resolution is limited. The vertebrates individually or in concentrations are probably of insufficient size and show insufficient contrast in emissivity to be detailed by present satellite instrumentation. Thus, aircraft sensors will probably be needed. The current aircraft which are available are limited in range; consequently, such surveys may present a difficult task.

4. Land, ice, or sea-based sensors.

Another type of remote sensing that may be particularly important is the use of remote sensors placed at the surface, which allows information to be transferred to ground base or satellite base data systems. This capability would be extremely valuable in the Southern Ocean, where access during the winter months is nearly impossible. Static platforms could be located in coastal regions with links to sensing systems in the water; alternatively, drifting sensing systems could be set adrift in the pack ice regions to monitor physical and biological parameters, as well as to pick up acoustical indications of seals, whales, and penguins.

In summary, the need for remote sensing in the Antarctic regions varies considerably depending on the species involved and the particular problem under study. However, it is clear that if we are going to evaluate and monitor successfully the biological resources of the Southern Ocean, it is essential: (a) to look to these techniques in the future, and (b) to begin to develop them now so that they may be adapted to the problems and situations unique to species of the Southern Ocean.

### 2.10.3 *Research programmes*

1. Existing and near future satellite data and instrumentation.

LANDSAT 1 has obtained three and one-half years of data on ocean turbidity which could be utilized in any pre-operational study. LANDSAT 2 was launched in 1975 and is working with much the same capabilities as LANDSAT 1. Unfortunately, the LANDSAT 1 imagery of the Antarctic is limited to south of approximately 65°S except for certain runs up the South American coast, which may render these data of little value. Nevertheless, the resolution is 75 x 56 m and sequential coverage is available every nine days. LANDSAT 2 has a similar coverage but could acquire data from other areas on command. If data are required from the sub-Antarctic islands, for example, a request to NASA for this coverage would probably succeed if the motivation were adequate.

Information on the extent of likely cloud contamination of satellite data can be obtained from the Temperature Humidity Infra-Red Radiometer Systems on NIMBUS satellites, and from the visible and infra-red systems on NOAA satellites. The extent of ice cover can be determined from the scanning microwave radiometer on NOAA5 and, after launch, from NIMBUS–G. The US Naval Weather Office produces maps of ice distribution in three-day averages. It is possible that such maps may be made available to scientific organizations.

2. Feasibility study of krill by remote sensing.

As a first step in the development of a krill remote sensing programme, a feasibility study should concentrate on acquiring imagery of krill swarms with currently operational sensors and at low cost. Therefore, the spectral and size characteristics of krill swarms should be measured as primary data for sensor specifications. Photographic spectro-radiometers and Low Light Level Television equipment should all be used.

The feasibility study should concentrate on the Antarctic Peninsula area in middle to late summer, and will require a long range small to medium sized aircraft with a fuel capacity of 10-12 hours flying time. High precision navigation equipment is essential, together with radar, a radar altimeter and standard camera hatch for sensor mounting. It is estimated that 50 hours mission time (total 100 hours) would be adequate for the feasibility study. Operations would be most convenient from bases on the southern tip of South America or in Antarctica.

3. Feasibility study of mammals and birds.

(a) Density and distribution studies by passive sensors.

At present no specific programme can be outlined, but it is important to initiate trials of various sensors such as water penetration film, running television systems and laser systems.

(b) Sensors for biological measurements of instrumented animals.

The development of instrumentation and monitoring stations to measure body temperature, heart rate and other physiological characteristics should be initiated. Techniques are well established for terrestrial vertebrates and circuitry is well advanced. The feasibility of using ocean buoys to relay data from instrumented animals to satellites should be considered. With larger animals it might be possible to transmit directly to satellites.

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## 3. PRACTICAL IMPLEMENTATION OF THE RESEARCH PROGRAMME

The objectives of BIOMASS require action along the following lines:

1. Seagoing operations of research vessels. These should include both detailed multidisciplinary studies in limited areas of special interest (co-operative 'experiments'), and large scale surveys which will build on the work carried out by such research vessels as the *Discovery, Ob* and *Eltanin* and by recent exploratory cruises.
2. Other operations at sea. Exploratory and commercial fishing and whaling vessels, supply vessels and others are expected to be operating in the Antarctic during the BIOMASS period. Observations from these vessels will be used to supplement the work of the research vessels, especially in relation to the harvestable resources. Seagoing operations should be supported by remote sensing work.
3. Shore-based studies. Investigations on feeding, growth and reproduction of krill and other key organisms at established coastal stations should complement and add year-round continuity to the offshore ship-based studies.
4. Data analysis. Arrangements will be made to ensure the proper compilation, storage, dissemination and analysis of information arising from all relevant activities in the Antarctic.
5. Modelling. Immediate use will be made of information from published and unpublished sources for the development of models; field and experimental data from (1), (2) and (1), (2) and (3) will be used to expand the models as they come in.

### 3.1 Seagoing activities of research vessels

During the first operational stage, culminating in the First International BIOMASS Experiment (FIBEX), 1980–81, investigations should be concentrated in a suitable area such as the Scotia Sea or the Atlantic sector in general. It is in this sector that the resources appear most abundant and where they are most likely to be harvested. Studies of other sectors must follow.

#### 3.1.1 *Macroscale studies of krill in relation to hydrography*

The drift of krill during its two to three years of life is of the order of 1 000 km, and is mainly governed by surface and deep currents. The assumed 'developmental ascent' may include the upper 2 000 m of the water column and, together with larval development, takes between 10 and 100 days. Two proposed projects are sufficiently wide ranging to provide information on transport mechanisms: the Weddell Sea Gyre project, and the International Southern Ocean Studies (ISOS) project on water circulation and remote sensing of the variability in oceanic fronts and ice movements. The near surface distribution of krill in summer has been described in considerable detail by earlier expeditions. However, little is known of the transport of the various life history stages and of the links between the different populations. Quantitative sampling of krill at several depths should be carried out in various areas and seasons: there is an urgent need to extend the life history studies of krill into autumn and winter and into the pack ice zone. The sampling programme should be guided by oceanographic observations and supported by radio echo surveys. At least two research vessels will be needed for each of the selected areas.

### 3.1.2 *Microscale studies on the ecology of krill swarms*

The interaction between phytoplankton composition and biomass and the swarming of krill under the influence of oceanographic factors can be studied at the rate of 10 km per 10 days; two to three ships are needed in a complete experiment of this type. Measurements to provide information on vertical transport and stability and on advection should be made, and samples taken in order to determine the spatial distribution and densities of swarms of krill in relation to the abundance and size spectra of phytoplankton, which will enable us to understand the reactions of a krill swarm to its food base and the effects of grazing on the phytoplankton. Quantitative recordings and sampling for analyses of phytoplankton distribution and zooplankton abundance and composition in different depth layers and at different times of day and night will provide additional information on the spatial structure of the biotic environment of krill. Echo sounding and sonar observations should provide three-dimensional pictures of the changes in time of zooplankton concentration.

These studies should be carried out at several selected places, mainly in areas of high krill concentration at the ice edge, in the neritic zone of the Antarctic Peninsula and of the Antarctic islands, as well as in the open ocean of the West Wind Drift, the East Wind Drift and the upwelling zones. If possible the studies should be repeated at different times of the year.

### 3.1.3 *Microscale studies of food chain structures and functions*

In order to learn more about possible future effects of krill fishing on the structure of the first and second trophic levels, the composition of phytoplankton and its productivity should be studied in places and seasons which differ in relative abundance of krill, salps or other herbivores. These studies must be based on quantitative plankton sampling at various depths, and can be considered as an extension of 2.2.2 into areas and seasons where alternative grazing and predation strategies lead to changes in the quantitative composition of the herbivore level.

### 3.1.4 *Macroscale studies of zooplankton, nekton and benthos*

There is still a need for further quantitative sampling of zooplankton, pelagic squids and fishes in various regions of the Southern Ocean, and the benthos of the Antarctic is poorly known. Quantitative data are needed on the abundance of the dominant elements of plankton and benthos in the different regions. The position of the dominant species within the food chains should be ascertained by studies of stomach contents and feeding apparatus. Benthos studies may be combined with observations on sedimentation and decomposition of fecal pellets, dead zooplankton, particularly krill, and diatoms. The biological and sedimentological surveys are very time consuming, and more than one research vessel will be needed, even if the intention is to cover only one oceanic sector each summer.

### 3.1.5 *Seagoing activities of other vessels*

The seagoing research tasks require the co-operation of a number of oceanographic and other vessels in the Southern Ocean. The majority of the seagoing studies need fully equipped research vessels, particularly the multidisciplinary studies on the relationship between krill and the environment. The success of the biological programmes will depend largely on good design and effective integration with physical studies of horizontal transport and vertical mixing. It would neither be sufficient nor economical to add small biological programmes to physical expeditions and vice versa, but full scale programmes of both disciplines could be combined. International co-operation is essential in view of the large support needed for a multidisciplinary study which includes several vessels and a considerable number of specialists.

## 3.2 Other ship-based programmes

The work of the research vessels can be greatly assisted by the co-ordinated survey efforts of exploratory and commercial trawlers, the few whaling vessels which are still in existence, and by supply ships and icebreakers. A brief summary of the advantages and limitations of the different types of vessels with regard to the research objectives of BIOMASS is given in Table 4. Given the ambitious objectives of BIOMASS, its success will depend on making the best use of all types of vessel.

In view of the importance given to resource management, there will be special emphasis on obtaining information from those vessels most directly concerned with the harvestable stocks, *ie*, exploratory and commercial vessels, particularly those directed at krill. This information will include details of the catch, the distribution and, as far as possible, the relative abundance of the stock, all of which are important in studying the population dynamics of the exploited stock. In addition, where opportunity offers, other biological observations using simple equipment such as plankton nets will be made from these and other non-research vessels.

Information from fishing vessels is, however, no substitute for observations from research vessels. Indeed, to the extent that the number of the former increases–in other words, exploitation intensifies–there will be a greater urgency for timely scientific advice on management, some of the information for which is only obtainable with well equipped research vessels.

### 3.2.1 *Utilization of ships*

1. Exploratory trawlers.

At present, exploratory trawling is being carried out in the Southern Ocean by ships from the Soviet Union, Japan, the Federal Republic of Germany and Poland, and this activity is likely to increase in the future. Each exploratory trawler has, at present, an active research programme, but these are being conducted largely in isolation from one another. This fleet of trawlers constitutes the largest single potential for supporting the proposed BIOMASS programme. Although the spectrum of opportunities available for oceanographic studies on such vessels is likely to be less than that on research vessels, their unique capacity for effective sampling of krill *en masse* and their sophisticated hydro-acoustic technology should be fully utilized. Successful liaison with the agencies operating these vessels would not only enhance the significance of their observations relative to one another, but would also provide 'ground truth' for other operations, such as acoustic surveys by other classes of vessels operating in the Southern Ocean, and remote sensing of surface swarms of krill. Exploratory trawlers (and commercial trawlers) have great potential for making significant contributions to our knowledge about krill swarms by taking simple qualitative samples of phytoplankton (mesh size 35 $\mu$m) and zooplankton (mesh size 200 $\mu$m).

2. Commercial trawlers.

At present, most of the commercial trawlers in the Southern Ocean operate in tandem with exploratory trawlers or research vessels, but their operations in the future could well be independent. Because these trawlers are dictated by considerations other than research, the spectrum of opportunity which they provide for BIOMASS is more limited than that provided by exploratory trawlers. However, the success (or failure) of their trawling operations and the gathered acoustic observations constitute data of prime importance if they can be extracted and integrated with those of other commercial trawlers. It would also be possible (with little extra effort) for the facilities of such trawlers to be extended in directions they might not normally cover, for example, acoustic surveys for squids as well as krill. The BIOMASS programme should also include plankton sampling at every trawling station by means of the simple free fall net.

TABLE 4. SUMMARY OF RESEARCH OPPORTUNITIES AND CONSTRAINTS FROM PLATFORMS AVAILABLE FOR SOUTHERN OCEAN STUDIES

| RESEARCH VESSELS | SHORE STATIONS | EXPLORATORY TRAWLERS | COMMERCIAL TRAWLERS AND WHALING SHIPS | SUPPLY SHIPS AND ICEBREAKERS | SATELLITES |
|---|---|---|---|---|---|
| | | CONSTRAINTS | | | |
| Limited (large scale) trawling capacity | Poor (large scale) trawling capacity<br>Limited access to open ocean<br>Limited geographic coverage | Limited spectrum of oceanographic opportunities | Uncontrolled operational area<br>Fishing bias<br>Narrow spectrum of oceanographic opportunities<br>Limited year-round coverage | Few station opportunities en route<br>Lack of trawling capability<br>Poor year-round coverage | Lack of 'ground truth'<br>Ice cover<br>Cloud cover<br>Turbulent sea surface |
| | | OPPORTUNITIES | | | |
| Flexibility<br>Multiple sampling capability<br>Interdisciplinary research<br>Water column studies<br>Acoustic surveys for krill, squids and fishes<br>Benthic sampling<br>Underwater photography | Stable platforms<br>Experimental studies<br>Year-round coverage<br>Time series studies<br>Inshore benthic sampling<br>Larval surveys<br>Sampling predators of krill, fishes, and squids (seals, penguins, etc)<br>Population dynamics of seals, penguins, etc<br>'Ground truth' for remote sensing of macro-algae | Acoustic survey for krill<br>Acoustic survey for squids and fishes<br>Efficient sampling for krill<br>'Ground truth' for acoustic survey of krill by other vessels<br>'Ground truth' for remote sensing of krill | Acoustic survey for krill and fishes<br>Efficient sampling for krill<br>'Ground truth' for acoustic survey of krill, squids and fishes<br>'Ground truth' for remote sensing of krill swarms<br>Squid and fish sampling from sperm whaling operations | 'Ground truth' for satellite survey of surface temperature and chlorophyll<br>Deployment of drifting sensors in communication with satellites<br>Occasional opportunities for time series observations near coast and at edge of pack ice<br>Observations on occurrence of seals and penguins | Remote sensing of surface temperature, chlorophyll, and krill swarms<br>Year-round coverage<br>Remote sensing for macro-algae<br>Communication with unmanned buoys and sensors |

3. Whaling ships.

There are still whaling vessels catching baleen and Sperm whales in the Antarctic. In addition to the information on whales that can be obtained from the activities of these vessels, they provide excellent opportunities for studying the animals eaten by the whales. No present fishing or research gear is as effective in sampling squid as the Sperm Whale. High priority should be given to making arrangements with the whaling companies for squid biologists or technicians to accompany their ships and to collect squid material. Biological observations should also be made of other animals (krill, fish, etc) eaten by whales. It would be particularly useful to determine whether the krill eaten by whales are similar in, for example, size or age to those caught by trawlers.

4. Icebreakers.

Much of the biological activity in the Southern Ocean occurs under the pack ice and to reach a proper understanding of the ecosystem one must take this into account. There is thus an urgent need for biological and also physical and chemical sampling beneath the ice. This work could best be accomplished by an icebreaker, fully equipped for oceanographic work and capable of biological sampling in deep water.

5. Supply ships.

Although constrained by time, the supply ships have great potential for adding to our understanding of the position of the polar front due to their widely spaced and fairly regular tracks. They can further assist by collecting data on temperature, salinity and chlorophyll. In this way, the supply ships can provide a broad network of ground truth for remote sensing by the NIMBUS–G Coastal Zone Colour Scanner, which will be providing simultaneous coverage over a broader area (See Section 2.10). It is recommended that the national Antarctic agencies operating supply ships be invited to take the major responsibility for this part of the BIOMASS programme. It would be useful if a working group were formed of those scientists from each national Antarctic agency responsible for the programme, representatives from the NIMBUS–G remote sensing team, and individuals experienced in continuous monitoring and processing of surface data.

The second role which supply ships, and icebreakers, could play in the BIOMASS programme is the deployment of drifting sensors in satellite communication with shore stations across the Southern Ocean. The technology exists for buoy and satellite communication (Creswell, 1976), for biomass estimates in the water column (Beamish, 1971), and for measurements of turbidity or transparency. A potentially powerful means could therefore be developed within the one buoy assembly for continuous and relatively inexpensive monitoring of krill swarms. It is recommended that the development of this technology be supported by BIOMASS and implemented as soon as possible.

The supply ships, and particularly the icebreakers, can further contribute to the BIOMASS programme by making observations on plankton over a period of days and possibly weeks around and in the pack ice. The Japanese supply ship *Fuji* is currently carrying out such a programme off Syowa station. These observations should be integrated with those of a similar nature carried out on platforms of floating ice from the shore stations.

### 3.2.2 *Recommendations*

1. That national agencies responsible for the operation of support cruises for scientific bases on the Antarctic continent be invited to execute a programme of underway surface observations of temperature, salinity, and chlorophyll in the Southern Ocean, together with the collection of XBT and underway echo traces from the upper 100 m; and that a representative from the NIMBUS–G CZCS survey be invited to join the working party to provide liaison with the remote sensing survey of surface properties.

2. That a working party be established to plan and execute a research programme on the dynamics of krill swarms—the programme should include routine plankton sampling from exploratory and commercial trawlers at each trawling station, collation of echo traces of krill swarms, and the deployment of drifting sensors in satellite communication; and that liaison be established with the working party co-ordinating underway observations from supply ships so that opportunities for time-series studies at the ice edge and in the pack ice from icebreakers and support ships are fully utilized.
3. That interest be invited and promoted in the development of a satellite communication drifting buoy assembly for studying the dynamics of krill swarms using sensors to measure zooplankton and phytoplankton biomass in the water column.

### 3.3 Shore-based studies

So far only a few experiments have been successful on krill and other Antarctic plankton organisms in captivity on board research vessels and at shore stations. Basic data on productivity, respiration, growth, and reproduction, should be obtained together with data on rates of filtration, feeding, digestion, and on metabolism under different controlled environmental conditions in tanks and aquaria. Attempts to culture krill experimentally should provide further information on the duration of various life history stages and on the biochemistry and histology of moulting and sexual maturation. Pressure tanks might be needed for the eggs and early larvae. Research on enzyme kinetics and microbial activity is needed in conjunction with studies on the energy budget and decomposition processes in large experimental enclosures.

Recently, considerable experience has been gathered from plankton experiments in various types of inshore and land-based enclosures. Studies in feeding and predation of krill under semi-natural and semi-controlled conditions might bridge the gap between the physiological laboratory studies and field observations. Experiments on shoaling, vertical migration and sonar target responses of marine organisms such as krill in enclosures would be complementary to field studies.

Year-round studies of the Antarctic fauna and flora are essential because most species have marked seasonal cycles. The shore stations—although limited in their seagoing facilities—provide opportunities for continuous year-round observations of plankton and benthos in near-shore communities, including their predation by fishes, seabirds, and seals. The great number of experimental studies and their methodological diversity require considerable international and interdisciplinary collaboration in more than one well equipped shore station with easy access to krill stocks. Further information is required on the programmes, technical facilities and manpower of the various stations, in order to launch new internationally co-ordinated programmes as outlined above.

#### 3.3.1 *Role of established shore stations*

The current phase of Antarctic near-shore marine research was initiated during the International Geophysical Year. This near-shore research was made possible by the establishment of a number of permanent research stations on the Antarctic continent and on island groups in the Southern Ocean which were manned throughout the year.

The principal roles of the established coastal stations in the BIOMASS programme are likely to be: to complement and add year-round continuity to the offshore ship-based studies; to analyse samples taken by the research vessels but which can be most successfully studied at the shore stations; and to study organisms which spend parts of their life histories in near-shore waters.

### 3.3.2 *Treatment of pelagic samples*

Preliminary treatment of the biological material collected is best carried out on board research vessels and then transferred to a sorting centre. However, analyses which must be made soon after collection, especially those which require precision weighting, are probably best done at an Antarctic shore station.

The biochemistry of the key organisms in the offshore regions at different trophic levels has yet to be described in any detail. Analyses of body tissue components are required to show seasonal variations and changes at different life stages.

### 3.3.3 *Near-shore hydrography*

The wide geographical distribution of coastal stations in the Southern Ocean facilitates year-round, simultaneous and standardized observations of the physical, chemical and biological parameters of coastal waters. These observations will complement data gathered during the offshore programme.

The routine techniques should be simple and unsophisticated in order to ensure the maximum participation by nations engaged in research in the Antarctic. Measurements should be made at fixed stations covering a long time series, as far as possible throughout the year. They should be taken at defined intervals and at standard depths. The most important parameters to be measured are: temperature, salinity, basic nutrients, light penetration, chlorophyll concentration, and concentration of suspended inorganic material, but it is desirable to make observations of as many relevant parameters as possible.

It is important to discover how measurements taken near the coast in such a programme might differ from the data collected by oceanographic vessels. Therefore, as far as possible it will be necessary to initiate projects to quantify the differences between neritic and offshore waters, to describe the interaction between the near-shore and offshore environments and to determine the magnitude or trend of any differences between them.

### 3.3.4 *Ecological studies and experimental research at shore stations*

Research will centre on investigations of the growth, metabolism, biochemistry, behaviour and reproductive biology of plankton and nekton species. The important potential research opportunities are:

1. Near-shore species.
    (a) Broad based energy budget modelling of the near-shore water column in order to identify the principal components, the main routes and rates of energy flow, and its potential contribution to the offshore ecosystem.
    (b) Research on the trophodynamics of large concentrations of breeding seals and birds and their impact on the neritic and offshore ecosystems.
    (c) Research on the biology of species which have part of their life cycle in near-shore waters but also comprise potential offshore living resources (*eg*, *Notothenia rossii*).
    (d) Research on accessible neritic species which are closely related to important offshore species (*eg*, the neritic euphausiid, *Euphausia crystallorophias*).
2. Offshore species.
    (a) Research on offshore species such as *Euphausia superba* held in aquaria at shore bases, including experiments on metabolism, growth, feeding and food assimilation rates.
    (b) The provision of cultures of offshore phytoplankton for basic studies on the

biochemistry and physiology of individual species and for feeding experiments with herbivores.

(c) Analysis of the characteristics of the bioluminescence emitted by offshore species in connection with the proposals to use remote sensing of zooplankton (Section 2.10).

(d) Controlled laboratory experiments to analyse the behaviour of appropriate offshore species, including shoaling and vertical migration, and to identify seasonal changes and changes during the ontogeny of each species.

(e) Research on shoaling, vertical migration and sonar target responses of marine organisms such as krill, using plastic enclosures at sites such as Cumberland Bay, South Georgia.

(f) Research on enzyme kinetics and micro-organism activity in conjunction with studies on the energy budget and decomposition processes.

### 3.3.5 *Existing facilities*

There are 39 coastal stations operated by 10 countries. Of these, 14 are engaged in marine biological programmes and 11 in marine vertebrate studies. The following information is required:

1. Number and location of coastal Antarctic research stations and the months during which each base is operational.
2. Capacity of station, number of scientists and technicians and opportunities for visiting scientists.
3. Whether marine projects are undertaken, and the routine marine sampling procedures undertaken.
4. Period of year during which marine projects are undertaken.
5. Logistic support and facilities available (including number and size of boats, diving facilities, submersibles, aquaria, chemical laboratories, etc).
6. Details of capital equipment normally available for laboratory and field studies in marine biology, physiology and biochemistry.
7. Programme of current marine studies and those planned for the future.

### SELECTED REFERENCES

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CRESWELL, G. R. 1976. A drifting buoy tracked by satellite in the Tasman Sea. *Australian Journal of Marine Freshwater Research*, Vol 27, p 251–62.

## 3.4 Data reporting and handling

### 3.4.1 *General*

The proposed large scale programme will generate information and data relating to all aspects of the living resources and their environment. Arrangements need to be made to ensure that individual scientists can easily locate all information (from whatever source) relevant to their particular studies. This will require some central organization (or organizations) which will have two rather distinct functions: (a) awareness, or cataloguing, and (b) information compilation and processing. The nature of the data handling problem also depends on the kind of data. For example, information on surface temperature or on the weight of a given species of fish caught in a commercial fishery, which can easily be expressed as single figures in standard and comparable units, presents different problems from complex biological information. Data from research vessels engaged in scientific work are always easier to obtain than data from commercial or semi-commercial operations. The mechanisms required are also likely to vary because different national agencies may be involved.

The following sections discuss, first, the actual technical work needed with respect to data of different types and from different sources, and secondly, the facilities required to do this work, and the commitments that must be undertaken by countries participating in research or harvesting activities in the Southern Ocean.

### 3.4.2 *Nature of activities*

1. Oceanographic data.

These include all types of observations on the physical and chemical characteristics of the water masses, which are important for understanding the environment of the living resources; a study of the impact of the physical environment on the abundance and distribution of these resources is especially important. Oceanographers, through national and world data centres, have well established arrangements for the exchange and central compilation of such data. Probably no new action needs to be taken other than to ensure that existing arrangements fully cover data from the Southern Ocean, with any minor modifications that seem desirable. Reporting, from whatever source, would probably be mainly the concern of IOC's co-operative programme in the Southern Ocean.

2. Catalogues of biological data.

Biological information includes a wide variety of types, from data on sizes of animals in commercial catches (which would probably be best handled in the same way as general statistical data) to samples of plankton, which may need special co-operative arrangements for sorting and taxonomic identification. Between these extremes lie most biological observations (*eg*, gross catches of major elements in plankton nets, observations on occurrence of echo-traces). Many of these observations are not suited for routine automatic processing because interpretation of the results (*eg*, the volume of the plankton net catch or the intensity of echoes) depends on qualitative information about the precise type of equipment, the way it was used and the type of organisms concerned. The major need with respect to these data is a register or catalogue, so that the interested scientist can readily discover what observations have been made and which organization or individual scientist should be approached for further information.

3. Sorting of biological samples.

Many biological samples, particularly plankton and benthos samples, but to a certain extent catches of larger crustaceans, molluscs and fish, contain a variety of taxonomic groups whose detailed identification requires specialized knowledge. A large part of the information concerning the sample (*eg*, total weight of plankton in the haul or the number of copepods) may be obtained at the time of observation, or soon afterwards. However, the scientist or institution making the collection may not have the detailed knowledge of some or all of the taxonomic groups to enable them to complete the sorting and identification. This is best carried out in specialized centres to which samples can be sent when the gross analysis has been completed and more detailed information is required. Bearing in mind the lack of adequate knowledge of most of the living resources in the region, such procedure will involve a fairly significant sub-sample of the total observations, including catches of fish and other organisms by commercial or semi-commercial vessels.

4. Statistical and related data.

It is convenient to consider together all of the biological and related data of a routine or semi-routine nature, particularly, but not exclusively, those arising from commercial or pilot scale observations. Such data include: statistics of total harvest (with details of species caught, and the location and time of capture); statistics of fishing effort (types of vessel and gear used, number of hauls, days of operations, etc).

The new data from individual countries or expeditions need to be combined to provide best estimates of quantities such as: the total catch of a species in a certain area during a particular period; the seasonal and year-to-year changes in abundance and distribution, as measured by changes in catch per unit effort; changes in size composition of the catches. The need to check on the reliability, consistency and comparability of the data can be time consuming; much of the information will come from commercial sources which may have little immediate interest in the quality of the data submitted. Again, those actively involved in harvesting a resource, but who have not submitted information, will need to be contacted. The data then have to be combined and published in tabulated forms (statistical bulletins, sampling reports) similar to those issued by regional fishery bodies in other parts of the world. This is presently done by the Bureau of International Whaling Statistics with respect to whaling; however, the volume of work would be much greater if harvesting of other resources began on a large scale.

5. Bibliographic information.

As the volume of publications on the living resources of the Southern Ocean grows, it becomes more difficult for the individual scientist without assistance to become aware of all significant new publications and to identify relevant material in the past literature. At least three information systems–the Cold Regions Bibliography Project, Library of Congress (which publishes *Current Antarctic Literature* and the *Antarctic Bibliography*); the Aquatic Sciences and Fisheries Information System, sponsored by FAO and other agencies (which publishes *Aquatic Sciences* and *Fisheries Abstracts*); and *Recent Polar Literature*, published by the Scott Polar Research Institute–are concerned with the living resources of the Southern Ocean, although they approach the subject as part of three quite different larger themes. There would seem to be little problem for these information services to produce specialized bibliographies of the so-called conventional literature (*ie* books, papers in journals) covering the interests of a SCAR project. There would be advantages in this being done by all three (preferably in conjunction) in view of their different coverage of technical and scientific journals.

The non-conventional literature, including mimeographed reports for meetings, and working party reports, is becoming increasingly important. In particular, most of the up-to-date information on exploratory and experimental fishing for krill is contained in this type of literature. Since such information is not always published in the normal scientific literature without long delay, it is essential that every effort is made to ensure wide distribution of the 'unconventional' literature and that information on availability is provided to appropriate centres.

### 3.4.3 *Facilities and commitments required*

1. General.

None of the information systems briefly outlined above will work unless proper facilities are available, and unless those individuals or institutions with the information provide it to the relevant system. Much of the work could be carried out within existing arrangements (though possibly some minor additional funding would be required to do the work effectively), while some would need some essentially new arrangements.

Oceanographic data can presumably be handled by existing national and world data centres; the commitment to supply data to these centres is generally accepted by oceanographers. Catalogues of biological data could also (in principle) be handled in the same way, though the volume of work may require additional funding. The existing ROSCOP and ROMBI forms may need adjustment for the particular interests of the Southern Ocean studies and all biological investigators will have to agree to complete these or some other type of report. This should present no problem with respect to observations made in the course of purely scientific studies, but may be more difficult in commercial or pilot scale operations.

2. Sorting of biological data.

Since study of the biological environment of the Southern Ocean will often require processing and identification of specimens by persons not involved in the actual collection, it is important that each sample be uniquely identified at the time of collection and throughout later examination and identification.

Standardized data recording and processing techniques were adopted on USNS *Eltanin*, which operated under the United States Antarctic Research Program (USARP) during its later cruises. Data recording forms (of which there were different kinds for pelagic and benthic sampling) were provided to all participants. Each form, in triplicate, was uniquely numbered; this number was henceforth the identification of the samples and the reference to all relevant data. In addition to recording basic data, forms for the study of living resources were also designed to record observations on abundance, size of organism, etc. These procedures accomplished at least two important objectives.

(a) There was no longer any confusion caused by different investigators assigning the same series of numbers to entirely different samples.

(b) Availability of forms, with established data fields, encouraged participants to record more observations in a consistent manner–a particularly relevant objective for large programmes in which the collecting operations will involve personnel who are less experienced than the programme directors.

Experience has shown that the sampling data should be summarized and reviewed for errors prior to the end of the cruise or soon thereafter. Recording of data on multi-copy forms facilitates this procedure of data quality control.

The Smithsonian Oceanographic Sorting Center (SOSC) has developed a computerized biological station data programme for data exchange and analysis. Data may be entered into a generalized master file that can be augmented as new information (such as identifications or bibliographic references) becomes available. With such a file, data and standard or special reports are readily available to the investigators. In addition, the file facilitates the publication and distribution of technical data in a timely and reliable manner. Participating countries can acquire the computer system and process data directly or send information to a centralized location for processing and distribution to all participating countries and individual scientists.

3. Statistical and related data.

As noted above, this work of data collection would be quite extensive once any significant harvesting (other than whales) began. Regional fishery commissions usually need several people (including clerical staff) to handle their statistical work. Technically, several institutions, including FAO, could carry out the work but would need additional funding. (FAO already handles these data on a global scale but without detailed breakdown except in those regions for which FAO has special responsibility. The lack of detail causes difficulty in interpretation; for example, the region of harvest is given in no more detail than, say, the south-west Atlantic, which covers an area from South Georgia to northern Brazil.)

A more serious problem might be that of ensuring fully detailed collection and reporting of data from commercial operations. Countries becoming members of regional fishery commissions normally accept commitments to supply data to the commission; a similar arrangement (in this case, to report data to SCAR and to other contracting parties) is contained in Article 5 of the Convention for the Conservation of Antarctic Seals. Arrangements and commitments of the same kind may need to be made with respect to any harvest made in the Southern Ocean.

### 3.4.4 *Proposals and recommendations*

Arrangements for exchange of information, and for the reporting, compilation and dissemination of appropriate data will be important features of the proposed programme. While many details can only be settled when the extent of research programmes and the scale of commercial exploitation are better known, the following specific actions can be recommended.

1. All oceanographic data should be reported to relevant centres.
2. Statistics of commercial and exploratory fishing should be reported to FAO along the lines set out in Appendix A, using the standard global classification of area and species. The proposed northward movement of the boundary lines between statistical areas in the Atlantic and Indian oceans was agreed to, and in the interim period before the new regions are formally approved by all interested parties, countries should distinguish separately, when reporting to FAO, the catches taken: (a) in the South Atlantic in the area bounded by 50° to 60°S in 20° to 50°W and 55° to 60°S in 50° to 60°W, and (b) in the Indian Ocean between 45° and 50°S in 30° to 80°E. Countries should also distinguish the major species as listed in the relevant section of this proposal.

   In view of the importance of proper statistics, it is recommended to SCAR that it draw the attention of Antarctic Treaty countries and other interested parties to the reporting of data on the catches taken.
3. Consideration should be given to the needs and possible arrangements for the exchange and storage of biological data, other than fishery data which could be handled by FAO.
4. Countries are urged to exchange early information on research being planned and being undertaken.

## 4. INTERNATIONAL CO-ORDINATION AND CO-OPERATION

There exists a number of international organizations, at various levels, which have expressed interest in the resources of the Southern Ocean (see Figure 6); several of these have active biological programmes. The success of BIOMASS will depend on the establishment of effective co-ordination machinery.

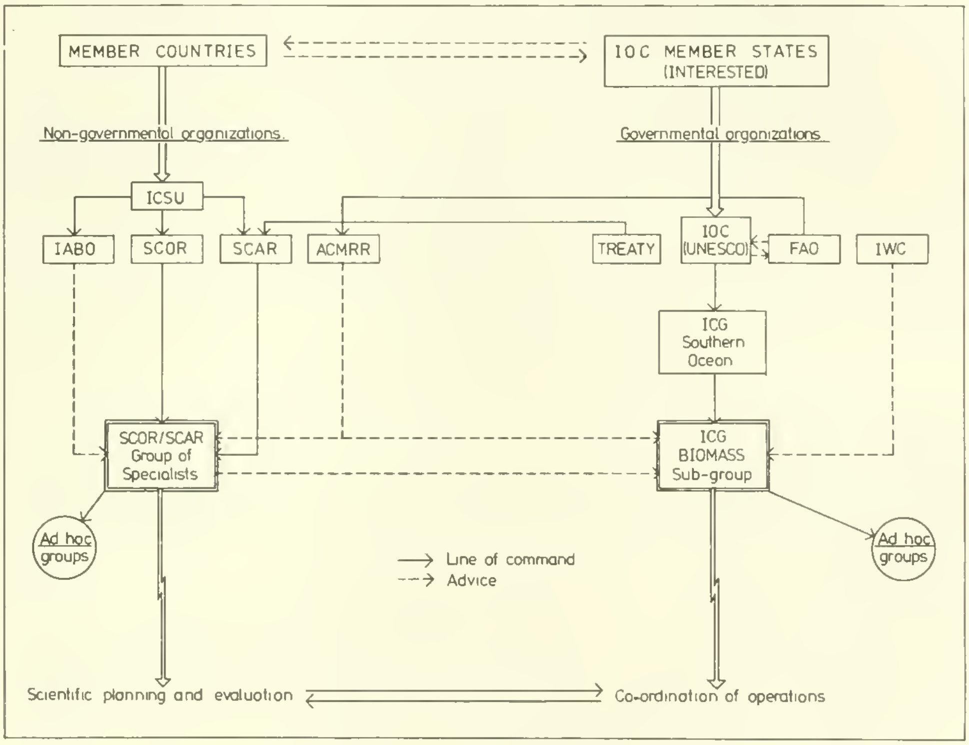
MEMBER COUNTRIES
IOC MEMBER STATES (INTERESTED)
Non-governmental organizations.
Governmental organizations
ICSU
IABO
SCOR
SCAR
ACMRR
TREATY
IOC (UNESCO)
FAO
IWC
ICG Southern Ocean
SCOR/SCAR Group of Specialists
ICG BIOMASS Sub-group
Ad hoc groups
Ad hoc groups
Line of command
Advice
Scientific planning and evaluation
Co-ordination of operations

FIG 6. Organizational structure for BIOMASS.

### 4.1 Present organizations

#### 4.1.1 *Non-governmental organizations*

1. ICSU-SCAR.
2. ICSU-SCOR.
3. ICSU-IABO.

#### 4.1.2 *Inter-governmental organizations*

1. Antarctic Treaty consultative meetings.
2. Biennial meetings of representatives of consultative governments.

3. Intergovernmental Oceanographic Commission (IOC) of UNESCO.

(a) While the IOC is constitutionally attached to UNESCO, it serves, with respect to marine research, as a 'joint specialized mechanism' of other interested UN bodies, specifically, FAO, WMO and IMCO, as well as the UN itself (ICSPRO organizations).

(b) IOC has a subsidiary body, an International Co-ordination Group for the Southern Ocean (ICG/SOC), established in 1970. It is composed of IOC member states interested in Antarctic research, with observers from SCOR, SCAR, ACMRR (FAO) and other interested organizations. The group is concerned with all aspects of Southern Ocean scientific studies and will need to maintain close co-ordination between BIOMASS and other SOC activities. ICG/SOC has the present terms of reference:

(i) To assemble and distribute details of firm oceanographic cruise plans in the Southern Ocean, preferably at least one year in advance.
(ii) To encourage the pre-allocation of blocks of time for oceanographic research on Antarctic supply vessels whenever practicable.
(iii) To develop means of co-ordinating existing and planned oceanographic research programmes in the region.
(iv) To encourage the evaluation of existing oceanographic data from the region with the intention of fostering specific studies of limited extent and capable of being carried out in the foreseeable future.
(v) To encourage and review the development of relevant theory, methods and instruments with particular reference to the problems of obtaining measurements in the winter and in the presence of ice.
(vi) To develop plans for the gradual evolution of a comprehensive study of the Southern Ocean.

(c) Having considered the recommendations of the second session of ICG/SOC (Buenos Aires, 15-19 July 1974) the IOC Executive Council invited the SCAR Group of Specialists on Living Resources of the Southern Ocean to prepare practical proposals for collaborative investigations on the biological oceanography of the area and for the organization of multi-ship studies.

(d) Global Investigation of Pollution in the Marine Environment (GIPME): the Intergovernmental Oceanographic Commission has published 'A comprehensive plan for the global investigations of pollution in the marine environment and baseline study guidelines' (IOC Technical Series No 14). Any activities in the Southern Ocean promoted under this programme by the IOC Working Committee for GIPME should be co-ordinated with BIOMASS.

4. The Food and Agriculture Organization of the UN (FAO).

The FAO has direct interest in the resources of the Southern Ocean and is already active in several spheres. Its main interests are in the better utilization and management of these resources rather than in scientific research in the narrow sense. However, a number of FAO activities are directly relevant to the BIOMASS project.

(a) The ACMRR of FAO (a body of scientists which, like SCOR, is also advisory to IOC) is presently active in evaluating the status of Antarctic resources of seals and cetaceans. The study is financed by UNEP, bilateral funds, and by FAO itself, and culminated in the World Scientific Conference on Marine Mammals held in Bergen in September 1976. An important feature of that conference was the formulation of a long term research programme on marine mammals. There will need to be close co-ordination between the proposed research programme concerning Antarctic stocks of seals and cetaceans and BIOMASS.

(b) FAO in 1974 convened an 'Informal consultation on Antarctic krill' (published as FAO/Fisheries Report, No 153). At this consultation the FAO Department of Fisheries agreed to:

(i) Produce a bibliography on Antarctic krill.
(ii) Produce updated accounts of the knowledge of the resource, its exploitation and utilization.
(iii) Act as an information centre on research plans, resource knowledge, fishing techniques, equipment and utilization questions.
(iv) Review (when appropriate) the need for international action such as *ad hoc* expert group meetings and joint research projects, and pursue the possibility of mobilizing international financing for resources survey work and other activities of a high priority.

Preliminary drafts of the bibliography and of the resource reviews, and an account of the exploitation and utilization of krill were presented to the Woods Hole meeting.

(c) FAO is the executing agency for a proposed Southern Ocean Fisheries Programme to be funded by the United Nations Development Programme. The preliminary phase of this programme started in July 1975 and is helping to support, among other activities, the resources reviews referred to in Section 2. The programme's main phase will include the compilation and dissemination of resource information. In addition, surveys of potentially exploitable resources, especially those which complement activities of other institutions, will be made to the extent of available support from UNDP and other funding agencies.

(d) FAO compiles and publishes statistical information on commercial fish catches and species categories by broad areas and on a worldwide basis. These data can provide essential basic information for resource studies, particularly if the regional and species classifications of Antarctic and sub-Antarctic catches were improved.

5. The International Whaling Commission (IWC).

The IWC has launched an International Decade of Cetacean Research, in response to proposals from UNEP and others. It has asked UNEP, FAO and perhaps other bodies for funds. It has been suggested that the World Bank might also be interested. IWC has also just embarked on a 'new management policy' for whaling by its member states, which requires considerably expanded research for effective application. The policy should reduce uncertainties in whale stock assessment and resolve problems arising from interactions between species.

6. United Nations Environment Programme (UNEP).

UNEP has a wide interest in environmental affairs, including the conservation of natural resources. It has helped support the ACMRR (FAO) study of marine mammals mentioned above.

7. International Union for the Conservation of Nature and Natural Resources (IUCN).

Quasi inter-governmental, IUCN has several levels of interest in Southern Ocean research: they range from expressions by its General Assembly of a more or less political nature, as to the desirable status and uses, or non-uses, of the Antarctic and the surrounding seas, to the various specialized groups—on whales, seals and now on marine mammals as a whole—under its Survival Service Commission. IUCN will be concentrating in 1977–79 on marine activities.

## 5. PROVISION FOR SCIENTIFIC ADVICE

### 5.1 Introduction

A major objective of the BIOMASS programme is to help ensure the wise and careful conservation and utilization of the living resources for the benefit of present and future generations of mankind. In particular, we hope to avoid the mistakes that have caused the collapse of many fish stocks. In view of these mistakes, it should be realized that the BIOMASS programme is a vital first step towards providing the necessary scientific information on different resources and their interactions. However, this will not ensure the wise use of these resources. Two other steps need to be taken: (a) examination of the technical aspects of different management strategies; and (b) presentation of the results of the scientific studies in a manner that will facilitate decision making by the governments concerned.

### 5.2 Examination of management strategies

Management, even of a single species, can be carried out in a number of different ways, and the number of alternatives increases rapidly when management is involved with a number of distinct but interacting resources. Management considerations in the Southern Ocean should include investigations on the economics and social condition of the fishery, as well as on its biology, since these can be critical in determining the success or failure of a management strategy. For example, one important weakness of the initial regime established by the IWC was that the overall Antarctic quota was not allocated to countries or to individual enterprises. As a result, a considerable over-capacity developed in the fishery during the 1950's; by 1964 the industry was in poor economic shape and not in a position to accept readily the substantial cuts in quota that the IWC Committee of Three then deemed to be necessary.

Commercial scale harvesting of krill may start in the near future, and it is unlikely that firm and precise estimates of the potential annual yield, (*ie*, the quantity that can be taken year after year without serious damage to the stocks of krill or other species) will be available by then. Two extreme reactions to this situation are: (a) to allow completely unrestricted fisheries for krill until the need for specific measures becomes obvious, or (b) to ban harvesting until better data are obtained. The dangers of the former, which has been the strategy implicitly adopted for many resources in the past, are now well known. The disadvantages of the latter are also great; first, it sacrifices the benefits that could accrue from adequately controlled krill harvesting during the interim period; second, it would be difficult, if not impossible, to determine the potential sustained harvest until some harvesting is done. Without significant exploitation, it is also difficult to estimate the effects of different levels of harvest on the detailed characteristics of the krill populations' abundance, growth, mortality or reproductive rates and on the other populations (whales, birds, etc) that interact with krill. The preferable strategy is one that allows some degree of harvesting, but under careful control and with arrangements to ensure that the harvest can be reduced quickly if there is any evidence that quotas have been set too high. It would, of course, be easier to detect changes if the harvest were concentrated in some limited area. The information obtained on the effects of harvesting on ecosystem relationships could then be used to develop management strategies for the whole area. This plan seems appropriate even though the population boundaries are still poorly defined.

The required studies will involve a variety of expertise in such subjects as economics, and biology (especially population dynamics). The model described in Section 2.2 of this proposal will obviously be basic but will need to be supplemented by careful analytical studies by experts in the fields concerned. The basic studies of individual stocks, proposed in Section 2, will be vital parts of the exercise.

### 5.3 Arrangements for providing advice

Administrators and other decision makers need scientific advice in a readily understandable form. Also, the management process, based in part on the scientific evidence, needs to be kept quite separate from the process of reaching agreement among scientists on interpretation of the scientific evidence. Experience in many fishery commissions has shown that progress towards administrative or political agreement on particular measures can be seriously impeded if scientific arguments are re-opened during the discussion. For example, negotiations on how to limit the catch of certain species to 100 000 tons, involving possible severe constraints on at least some fishermen, will soon break down if it is suggested that perhaps the limit need not be lower than 150 000 tons.

Agreement between scientists in this sense does not necessarily mean unanimous agreement on some single figure. It must be expected, given our uncertainty about the structure and functioning of the Southern Ocean ecosystem, that there will be considerable differences in interpretation. Any scientific statement or advice used in management decisions must take these doubts and differences into account. This can be done within a single agreed report, provided the differences and their implications (especially with regard to the results of different management measures) are spelt out.

If such a report is to be accepted and used by the decision makers as a single agreed document, all concerned scientists must, in principle, be able to participate in the discussions and the preparation of the report. In fishery commissions this function is usually carried out by a ‘standing committee on research and statistics’ (a title that reflects the importance of statistics and similar data to the whole process) or an equivalent body set up within the commission. However, in the case of the two commissions in the north-east Atlantic (including the Baltic) this function is carried out by the International Council for the Exploration of the Sea. For practical reasons, the main work is often done by small subcommittees or working groups, usually consisting of specialists on stock assessments. The experience of the fishery scientists working in these groups is that groups of specialists, though normally nominated by and representative of their national governments, do work effectively together and are generally highly successful in carrying out the scientific work. The degree of co-operation and success tends to increase with time, particularly if the group has had the chance to work together before difficult and politically sensitive problems of management occur. The fishery commissions often have other standing committees or groups to examine technical, but wholly biological, questions concerning economic, social or other problems related to determining alternative management measures.

Similar arrangements for detailed examination and review of scientific and technical aspects may be desirable for the Southern Ocean. Although consideration of the structure of such a group is outside the scope of this document, once large scale exploitation starts and the responsibilities of the scientific planning group increase, its effective functioning will require some semi-permanent secretariat to provide support regarding such matters as compiling routine data, processing reports, and servicing meetings (which are likely to become fairly frequent). It may be desirable to arrange for additional contributions to the group from those experts who are concerned with more long term interests, particularly in relation to the problems of the world community as a whole.

The introduction and implementation of management measures will require some formal inter-governmental arrangements; the establishment of the necessary structure will call for extensive international discussions, taking into account a large number of factors, of which scientific research will be only one.

## 6. TIME-TABLE FOR BIOMASS

The three major types of activity in the BIOMASS programme (seagoing experiments and surveys; shore-based experiments and year-round observations; data analysis and modelling) have to be adjusted to each other. Observations on krill swarms and on the ecological physiology of key organisms of the Antarctic ecosystem should be started immediately and continued both at sea and at shore stations. Systems of data reporting and handling should be developed as soon as possible. The programme by FAO as discussed and approved by its Committee on Fisheries includes the development of a statistical data base and of a collection of scientific reviews on the living resources and their present and potential exploitation. Some standardization with regard to sampling and sorting of plankton and nekton in the Southern Ocean is also required at an early stage of the BIOMASS programme.

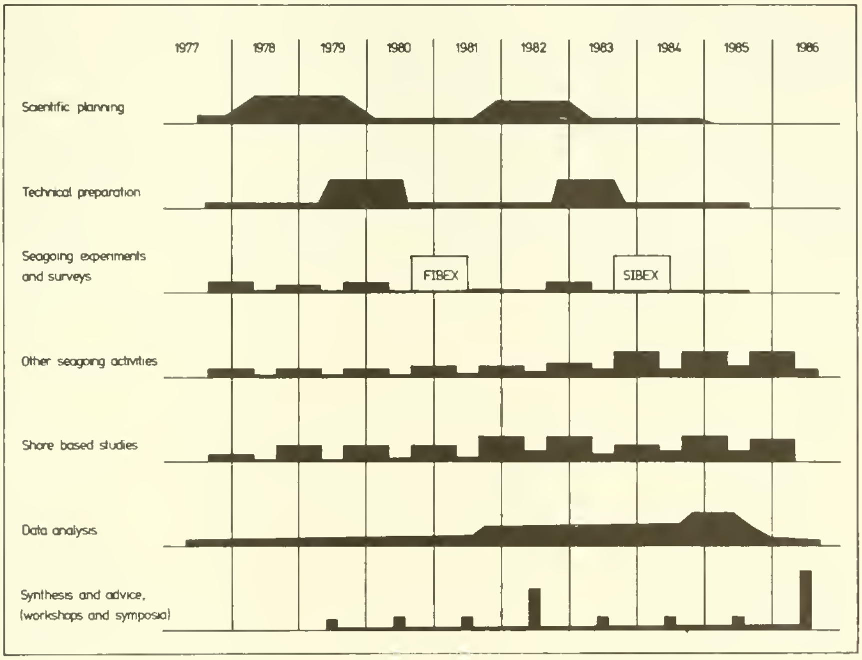

FIG 7. Time-table for BIOMASS.

The main implementation phase consists of at least two major international multi-ship experiments as well as of a number of loosely connected experiments at sea and ashore and large scale surveys at the national level. A time-table for large scale seagoing operations has not only to take into account other major oceanographic activities such as FGGE but also the need for sufficient time for scientific planning, logistic preparation, and development of instrumentation.

The austral summer 1980–81 has been chosen for the First International BIOMASS Experiment (FIBEX)—a major multidisciplinary process-oriented study involving several vessels in small scale experiments and large scale investigations of transport mechanisms and ecosystem variability in space and time. Operations will concentrate on the Atlantic sector but include Drake Passage and its western approaches. Current marine research activities in the Antarctic should be used as far as possible to prepare the ground for this first BIOMASS experiment. Data analysis will be carried out in conjunction with field work, laboratory studies and modelling. Small groups of specialists will need to meet to plan seagoing and shore-based experiments, and to develop methodology, data handling and modelling concepts. An interim synthesis of data and results should be presented at specialized workshops from 1979 onwards and at a small symposium in 1982. The complete results should be ready for presentation at a major symposium in about 1986.

## 7. PLANNING AND CO-ORDINATING GROUPS

Preparatory and co-ordinating arrangements for the implementation of BIOMASS will be needed at the scientific and administrative, non-governmental and governmental levels. The group felt that such arrangements should largely be entrusted to the existing bodies of SCAR/SCOR and of IOC, which should also be the principal sponsors of BIOMASS.

The group proposed that a SCAR/SCOR scientific planning group be established which would recommend methods and techniques and draw up scientific programmes for co-operative field work and shore-based studies and for the analysis of data. Sub-groups could be established for special technical tasks. The existing Group of Specialists on the Living Resources of the Southern Ocean (SCOR WG 54) could, with perhaps enlarged membership and its new terms of reference, undertake such a task.

The group further proposed the formation of a BIOMASS co-ordinating group as a sub-group of the existing IOC International Co-ordination Group for the Southern Ocean (ICG/SOC), with responsibility for the implementation of the BIOMASS programme acting on the scientific advice of the SCAR/SCOR scientific planning group. Consideration might be given to the appointment of an international co-ordinator. SCAR, SCOR and IABO should be invited to participate in the work of the BIOMASS co-ordinating group, and it is expected that FAO and the International Whaling Commission will contribute to the efforts of this group.

The proposals on the co-ordination of BIOMASS and on exchange of information and data are summarized in the recommendations given in the following section.

# 8. COMPILATION OF RECOMMENDATIONS ON THE ORGANIZATION OF BIOMASS

The Group recommends:

1. That SCAR and SCOR approve the following amended terms of reference for the Group of Specialists on Living Resources of the Southern Ocean (SCOR WG 54).
   (a) To encourage and stimulate investigations of the trophodynamics of the Antarctic marine ecosystem and the ecology and population dynamics of organisms at different trophic levels.
   (b) To keep under review the current state of knowledge concerning the Antarctic marine ecosystem from the viewpoint of structure, biomass and dynamic processes of organisms at different trophic levels.
   (c) To transmit through SCAR and SCOR to those countries engaged in the exploitation of the living resources of the Southern Ocean scientific information relevant to the management of such resources.
   (d) To advise SCAR and SCOR and through them other international organizations, and in particular to respond to relevant recommendations of IOC and the Antarctic Treaty consultative meetings.
   (e) To act as the international scientific planning group for BIOMASS.
   (f) To recommend standardized measurements, techniques and data recording of biological observations in the Southern Ocean.
2. That IOC undertake the international co-ordination of BIOMASS.
3. That IOC request countries carrying out research in the Southern Ocean to provide details of proposed cruise tracks and scheduled researches, which would be made available to the Group of Specialists.
4. That SCAR request the National Agencies operating supply ships to institute a circum-Antarctic programme of underway observations of surface temperature, salinity, chlorophyll and underway collection of records of expendable bathermograph (XBT) and biological echo traces.
5. That SCAR collaborate with FAO in drawing the attention of all parties engaged in the exploration and exploitation of living resources of the Southern Ocean to the need for detailed catch and effort statistics as set out in Annex A to be submitted to FAO.
6. That SCAR inform FAO of its approval of the proposed northward movement of the boundary lines between statistical areas in the Atlantic and Indian oceans, and that in the interim period before the new regions are formally approved by all interested parties, countries should be requested to distinguish separately, when reporting to FAO, the catches taken (a) in the south Atlantic in the area bounded by 50° to 60°S in 20° to 50°W and 55° to 60°S in 50° to 60°W, and (b) in the Indian Ocean between 45° and 50°S in 30° to 80°E.

# APPENDIX A

## Statistics from commercial fisheries

As discussed in the main proposal (particularly Section 3.4.3), it is essential for the success of BIOMASS, and for the rational utilization and management of the resources, that scientists have available to them detailed statistics from any commercial fisheries in the Antarctic. The following proposals have been made regarding the details of the statistics that should be reported to FAO as soon as possible following the end of each Antarctic season:

1. The catches.

The quantities should refer to nominal catches, *ie* the live weight of the animals as they leave the water, before any processing takes place. These nominal catch data, reported in metric tons, should be broken down as follows:

(a) *Time periods*: These should be in calendar months. Annual summaries should be for split years (1 July–30 June).

(b) *Species items*: These categories should refer preferably to individual species, but in some cases (for example, cephalopods) to groupings by genera or even families.

(c) *Fishing areas*: The catch data reported should refer to quadrangles of 5° latitude by 5° longitude; if this amount of detail cannot be provided, then the areas should refer to three FAO 'Major Fishing Areas' for statistical purposes, *ie* FAO Areas 48, 58 and 88.

(d) *Fishing gear*: The catches should be broken down by the principal fishing methods used (for example, trawls, purse-seines, longlines, etc) listed in FAO's International Standard Statistical Classification of Fishing Gear.

2. Fishing effort and corresponding catches.

For nominal catches (reflecting the details discussed in the preceding paragraph) the *corresponding* fishing effort should also be provided for each 'kind of fishing unit'. The fishing unit is determined primarily by the gear used, and secondarily by the size (GRT) of the vessel. The information on fishing effort should cover 'fishing time' and 'fishing power'. 'Fishing time' concepts are related to the type of gear used. For trawls, the principal effort measure is 'number of hours fished', for purse-seines the 'number of sets'. Standard definitions for these and other effort concepts have been established by the Co-ordinating Working Party on Atlantic Fishery Statistics and are under constant refinement and review by that body.

3. Fishing fleets.

Details should be given by national offices on all the individual units (mother ships, factory vessels, fishing vessels, etc) of their fleets operating in one or more of the three FAO Antarctic Fishing Areas during a specified split year, 1 July–30 June. For each of these vessels such information should be provided as: (a) its nationality and name, (b) type of vessel, (c) overall length, (d) gross registered tonnage, (e) horsepower, (f) type or types of fishing gear, (g) personnel, (h) hold capacity for various products, (i) special processing equipment, electronic equipment, etc.

The following documents, available from the Fishery Statistics Unit, Department of Fisheries, FAO, Rome, provide detailed information on statistical standards and requirements:

*A proposed international statistical system for the Antarctic fisheries–FAO Fishing Areas 48, 58 and 88* (FAO Fisheries Circular No 608).

*World chart: Major fishing areas for statistical purposes* (FAO Fisheries Circular No 420).

## APPENDIX A:

*'Nominal catches' and 'Landings': Definitions and notes* (FAO Fisheries Circular No 428).

*Notes on international classifications and definitions used in fishing fleet, fishing gear, fishing effort and fishermen statistics* (FAO Fisheries Circular No 429).

## APPENDIX B

### Participants

### SCAR/SCOR Conference on Living Resources of the Southern Ocean
Academy Summer Study Center
Woods Hole, Massachusetts, USA
17–21 August 1976

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## APPENDIX C

### Acronyms

| | |
|---|---|
| ACMRR | Advisory Committee on Marine Resources Research of FAO |
| CARPAS | Commission Assessores Regionale del Pesquerias del Atlantico Suroest (members: Brazil, Uruguay, Argentina). Subsidiary body of FAO, set up under Article VI of FAO constitution. |
| FAO | Food and Agriculture Organization of the United Nations |
| FGGE | First GARP Global Experiment |
| FIBEX | First International BIOMASS Experiment |
| GARP | Global Atmospheric Research Programme |
| GIPME | Global Investigation of Pollution in the Marine Environment |
| IABO | International Association for Biological Oceanography of IUBS |
| ICSEAF | International Commission for the Southeast Atlantic Fisheries (members: Spain, Portugal, Japan, USSR, Bulgaria, Poland, South Africa). Independent, H.Q. in Madrid. |
| ICSPRO | Inter-Secretarial Committee on Scientific Programmes Related to Oceanography |
| ICSU | International Council of Scientific Unions |
| IMCO | Intergovernmental Maritime Consultative Organization (UN) |
| IOC | Intergovernmental Oceanographic Commission |
| IOC's ICG for the Southern Ocean | IOC's International Co-ordination Group for the Southern Ocean |
| ISOS | International Southern Ocean Studies |
| IUBS | International Union of Biological Sciences |
| IUCN | International Union for the Conservation of Nature and Natural Resources |
| IWC | International Whaling Commission |
| NASA | US National Aeronautics and Space Administration |
| ROMBI | Results of Marine Biological Investigations |
| ROSCOP | Report of Observations or Samples Collected by Oceanographic Programmes |
| SCAR | Scientific Committee on Antarctic Research |
| SCOPE | Scientific Committee on Problems of the Environment |
| SCOR | Scientific Committee on Oceanic Research |
| SOC | Southern Ocean Co-ordination Group |
| UNDP | United Nations Development Programme |
| UNEP | United Nations Environment Programme |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| WMO | World Meteorological Organization |

# APPENDIX I

## COMMENTS ON THE

## DRAFT ENVIRONMENTAL IMPACT STATEMENT

## BY

## FEDERAL AGENCIES

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UNITED STATES ARMS CONTROL AND DISARMAMENT AGENCY

RECEIVED
OES

1978 MAR 21 PM 2 41

March 20, 1978

DEPARTMENT OF STATE

MEMORANDUM

TO: William Mansfield - Department of State, Office of Environmental Affairs

FROM: Walter L. Baumann - ACDA, Office of the General Counsel

SUBJECT: Comments on the Draft Environmental Impact Statement on the Negotiation of a Regime for Conservation of Antarctic Marine Living Resources

The Arms Control and Disarmament Agency has reviewed the subject EIS forwarded by Mr. Sellin's Memorandum dated February 2, 1978, and has no comments concerning the environmental aspects of the EIS. However, ACDA is deeply interested in the preservation of the Antarctic Treaty. The provisions of the Treaty requiring that Antarctica be used for peaceful purposes only, suspending territorial claims, prohibiting nuclear explosions and disposal of radioactive waste, and providing for on-site inspections are particularly valuable from an arms control perspective. It is essential that these provisions remain unaffected by the current negotiations for a Regime to conserve living resources.

ACDA/GC:
WLBaumann
ams:MAR 20, 1978

CENTRAL INTELLIGENCE AGENCY
WASHINGTON, D.C. 20505

16 FEB 1978

Mr. William H. Mansfield III
Office of Environmental Affairs
Department of State
Washington, D.C. 20520

Dear Mr. Mansfield:

We appreciate the opportunity to review the draft Environmental Impact Statement for a Possible Regime for Conservation of Antarctic Living Marine Resources; however, we have no comment on the draft submitted.

We have no jurisdiction by law or special expertise concerning this matter.

Sincerely,

James H. McDonald
James H. McDonald
Director of Logistics

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UNITED STATES DEPARTMENT OF COMMERCE
The Assistant Secretary for Science and Technology
Washington, D.C. 20230
(202) 377-3XX 4335

April 11, 1978

Mr. William H. Mansfield III
Office of Environmental Affairs
Department of State, Room 7820
Washington, D.C. 20520

Dear Mr. Mansfield:

This is in reference to your draft environmental impact statement (DEIS) entitled, "DEIS for a Possible Regime for Conservation of Antarctic Living Marine Resources". The enclosed comments from the National Oceanic and Atmospheric Administration (NOAA) are forwarded for your consideration.

Thank you for giving us an opportunity to provide these comments, which we hope will be of assistance to you. We would appreciate receiving twelve copies of the final statement.

Sincerely,

Sidney R. Galler
Sidney R. Galler
Deputy Assistant Secretary
for Environmental Affairs

Enclosure:
Memo from Mr. Robert F. Scott, Acting Assistant Director
for Scientific and Technical Services

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Washington, D.C. 20235

MAR 7 1978

MAR 2 7 1978 F53/RM

TO: Dr. William Aron, Director
Office of Ecology and Conservation, EE

FROM: Robert F. Scott
Kenneth R. Roberts for
Acting Assistant Director for Scientific
and Technical Services, F5

SUBJECT: Review of DEIS No. 7802.01 - For a Possible Regime for
Conservation of Antarctic Living Marine Resources (DOState)

The draft environmental impact statement that accompanied your memorandum of February 2, 1978, has been received by the National Marine Fisheries Service for review and comment.

The statement has been reviewed and the following comments are offered for your consideration.

Six alternatives for the consideration of a conservation regime were forwarded in the Draft EIS. We believe the proper choice was made because a conservation regime will be established together with the objective functions and machinery necessary to fulfill proper conservation measures.

The proposed conservation regime includes the establishment of a body with the authority to determine conservation needs and to request harvesting accordingly. We do not believe that the Scientific Committee on Antarctic Research (SCAR), an affiliate of the International Council of Scientific Unions, or the Scientific Committee for Oceanographic Research (SCOR) are the proper agencies by themselves to handle this responsibility. The body should consult both, with nations that now participate in the commercial harvest (or which contemplate such participation in the future), and nations not desiring such participation but having a strong interest in the conservation of the basic fishery stocks. This should insure a balanced mix of management, conservation and academic research perspectives in the composition of the body.

1 The DEIS should contain more information on past and present exploitation details (especially for krill) and, if possible, what plans are being made by specific member nations to exploit krill in the proposed conservation zone. For example, it is our understanding that several nations have made plans to initiate the commercial fishing of krill and are currently "gearing up" to accomplish this objective. Although some mention of the exploitation of krill is given throughout the appendices, no specific tabulation of exploitation by country is given, and it should be.

Other comments based on our DEIS and Appendices review follow:

1. It was mentioned that the Scotia Sea is the only known breeding area for krill--this area should be rigorously protected while other (?) breeding areas are identified.

2 2. The question of mineral resource exploration and oil contamination has been raised at the Ninth Antarctic Consultative Meeting held December 1977. No mention was made of exploratory oil drilling, although in discussions of this subject between staff members, oil drilling permits were intimated. The Conservation Zone discussions should include these subjects, i.e., mineral and oil exploration and identify the future plans of participating nations. The DEIS should also include these subjects if they are to be related subjects. To date the DEIS only states, "The activity of concern in terms of environmental impacts on the Antarctic marine ecosystem is commercial harvesting of renewable resources."

3. On page C-12, reference is made to the impracticability of importing new species of fish (salmon) to feed on Antarctic krill in the conservation zone. We feel that this specific area of research should be, at least, kept open for future exploration. No research on this subject was proposed in the BIOMASS proposal.

4. The main point made in the Appendices was that unwise exploitation in Antarctic waters, could trigger disastrous changes throughout the ecosystem: There are virtually no estimates of the abundance and biomass of fish populations, nothing known about the squids and only very rough estimates of krill stocks.

cc: F5 F53 F53(Massey) F11 F11(A.T. Pruter)

EXECUTIVE OFFICE OF THE PRESIDENT
COUNCIL ON ENVIRONMENTAL QUALITY
722 JACKSON PLACE, N. W.
WASHINGTON, D. C. 20006

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ARTMENT OF STATE

March 13, 1978

MEMORANDUM FOR WILLIAM MANSFIELD

FROM: Lee M. Talbot

SUBJECT: CEQ Comments on Draft EIS for a Possible Regime for Conservation of Antarctic Marine Resources

This is a good EIS because it clearly points out the options and dangers of the proposed actions. However, the following items should be emphasized.

1. We should stress the need to know turnover rates of resources as well as stocks. For a long time man has been too impressed with large plant and animal biomass without realizing that some times nature builds up biomass painfully slow. Harvesting of certain rain forests has demonstrated that a large biomass can disappear quickly if the rate of exploitation exceeds a slow production. To avoid these pitfalls, pages 1 and 2 of the proposed federal action should add the words "turnover rate" everytime the "need to measure standing stocks" is mentioned (three times). Harvest allocations cannot only be based on stocks, but must consider the rate of stock production.

2. Krill is the central issue, and the EIS discusses it well. However, certain key points should be stressed.

3 a. We don't know the rate of production of krill nor do we know how many breeding stocks there are. It is possible that only one breeding stock exists (page 35)!

b. Krill is the central food item and indeed the only apparent mechanism to concentrate the primary productivity of the Antarctic waters into all other food chains (Fig. 2, page 24).

c. Krill is long-lived relative to zooplankton and other similar organisms.

c. Any krill harvest will come out of what is now consumed by predators and NOT from some hypothetical part of the stock which is not utilized by predators (page 23).

These four facts have serious implications. For example, krill is not a new food supply for the developing countries. The world has been harvesting krill all along by harvesting the fish, marine mammals, and other vertebrates of Antarctica. Between 1945 and 1960, 30,000 to 40,000 whales were harvested annually. The question is what is the best strategy of resource management: harvesting and processing of krill or harvesting the predators of krill? A strong case can be made that there is more net yield and better energy use efficiency in the harvesting of the krill predators. The fact that historically the fishery developed this way provides support for this view.

4 The facts given above should also provide the constraints on expected krill catches. It appears that some people are expecting to harvest more krill (150-200 million tons) than the total world catch of fish (70 million tons) (page 36). This is absurd. The EIS clearly points out that the Antarctic waters are no more productive than any other oceanic waters (page 16). To think that those waters will outproduce the rest of the world's fishery is incorrect. Since the areas of high productivity in Antarctica are discrete (page 16), they should be mapped as part of the scientific effort. This will be necessary if the management of the whole ecosystem is going to maintain the long-term productivity of that system. The naive view that all of the Antarctica's waters are as productive as is the edge of the ice must be disspelled.

In view of the inadequate ecological understanding of the region and the fact that a "limited period of years" are mentioned with prominence on pages 6 and 7, the soundest scientific approach would be that (a) those years be used to find out answers about the longevity, reproduction rate, and productivity of krill and (b) no krill be harvested until such information is available. The proposed fixed annual increase in the krill catch over a finite and limited number of years (page 6) is contrary to the spirit of the Antarctic Treaty because it could irreversibly alter the whole ecosystem.

Department of Energy
Washington, D.C. 20545

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MAR 20 1978 NT OF STATE

Mr. William H. Mansfield III
Office of Environmental Affairs
Room 7820
Department of State
Washington, DC 20520

Dear Mr. Mansfield:

This is in response to the transmittal dated February 1, 1978 in which the Department of Energy (DOE) was invited to review and comment on the Department of State's draft environmental impact statement concerning a possible regime for conservation of Antarctic living marine resources.

We have reviewed the statement and have determined that the proposed action will not conflict with current or known future DOE programs. We have no comments to offer on the statement itself.

This is also to inform you that since the Energy Research and Development Administration and the Federal Energy Administration were merged into the Department of Energy on October 1, 1977, along with the power regulating functions of the Department of the Interior (Bonneville Power Administration, Southeastern Power Administration, Southwestern Power Administration, Western Power Administration and Alaskan Power Administration), draft environmental impact statements previously sent to NEPA contacts at headquarters, field, or regional offices of these organizations should be immediately discontinued. In the future, impact statements that your agency requests the Department of Energy to review should be sent to:

Director
Office of NEPA Affairs
U. S. Department of Energy
Mail Station E-201, GTN
Washington, DC 20545

In order to provide a timely DOE agency-wide review of draft environmental impact statements, a minimum of eight copies should be transmitted. We require four copies of final environmental impact statements.

Thank you for the opportunity to review and comment on the draft statement.

Sincerely,

W H Pennington

W. H. Pennington, Director
Office of NEPA Coordination

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

In Reply Refer To:
ER-78/115

MAR 29 1978

Mr. William H. Mansfield, III
Office of Environmental Affairs
Department of State
Room 7820
Washington, D.C. 20520

Dear Mr. Mansfield:

The Department of the Interior has reviewed the draft environmental statement for a Regime for Conservation of Antarctic Living Marine Resources, as requested in your letter of February 1, 1978. Except for two minor comments listed below, the document adequately considers those areas within our jurisdiction and expertise.

The Management Options, on pages 8 and 33, discuss the area to be covered by the regime. Although the Antarctic Convergence position varies, it can be located by its physical oceanographic measurements and its biological boundaries. We believe this means of defining the area would be the most specific manner of setting the boundary.

5 Eight agreements pertaining to the marine environment in the Antarctic are listed on page 10. A summary of each agreement and their participants would be beneficial to reviewers of the final statement.

We hope these comments will be of assistance to you.

Sincerely,

Larry E. Meierotto
Deputy Assistant SECRETARY

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MARINE MAMMAL COMMISSION
1625 EYE STREET, N. W.
WASHINGTON, DC 20006

20 March 1978

Mr. William Mansfield, III
Office of Environmental Affairs
Department of State
Washington, D.C. 20520

Dear Mr. Mansfield:

Thank you for the opportunity to comment on the "Draft Environmental Statement for a Possible Regime for Conservation of Antarctic Living Marine Resources, February 1978"

As a general comment on procedure, the Commission, having recommended since 1976 that an environmental impact statement be written preparatory to negotiation of such a regime, views the timing of the Draft Environmental Impact Statement (DEIS) as unfortunate, particularly in light of the extreme importance of the proposed convention.

6 Preliminary negotiations of substance will have already taken place in Australia before comments on the DEIS are due and before they can be adequately considered. Assuming that the Department did not intend to produce draft and final impact statements in preparation for the Canberra meeting and that important information will have been developed during the course of that meeting concerning environmental impacts and options not included in the present draft, the Commission recommends that the DEIS be rewritten with reference to the comments received as well as the results of the Canberra meeting and reissued as a draft or supplement. Issuance of a final Environmental Impact Statement should be delayed pending consideration of and comments on the revised DEIS. The revised or supplemental DEIS should clearly identify the schedule for actions as well as the role and timing of the Environmental Impact Statements in the decision process. In addition, it should include all relevant documents resulting from the Canberra meeting so that those who were not present can review and comment on the proposed action within a realistic framework.

## Proposed Federal Action

The discussion of the proposed Federal action contains too little detail to allow for meaningful evaluation and is in need of substantial expansion. Here and elsewhere, the basic problem with the DEIS appears to be the result of the fact that the details of the proposed action have not been developed, except in broad, general terms which must be refined before the environmental impact of the proposed action and alternatives can be assessed.

Although it is stated that "the purpose of the regime would be to ensure that any harvesting of Antarctic marine living resources take place in accordance with sound conservation principles and practices...", the principles and practices set forth on pages 1 and 2 are too general to be meaningful. "Overexploitation", by itself, for example, is not a term to which one can attach specificity. Its meaning depends on what is considered to be the proper level of exploitation, and the DEIS fails to identify this standard. Similarly, "adversely affect" is not defined anywhere. Obviously, a central question is whether the goal is to keep populations at optimum sustainable population levels, maximum sustainable yield levels, optimum sustainable yield levels, or above "endangered" or "threatened" levels. The discussion should be expanded to include a meaningful listing of conservation principles and practices as well as definitions of terms used.

As is the case with the description of the purposes of the regime, the actions set forth on pages 1 and 2 to accomplish these purposes are not fully developed here or elsewhere. The discussion of the necessary actions should be expanded to include, for example: acquisition of reliable information on the natural history, distribution, density, productivity, and feeding habits of each species and/or population that could be directly or indirectly affected by harvesting or associated activities; acquisition of reliable information concerning species relationships and the biological and/or physical factors which presently are regulating the distribution and abundance of species that could be directly or indirectly affected by harvest or associated activities; identification of species and/or stocks to which conservation measures should be applied; development, implementation, and effective enforcement of quotas, regulations, etc. designed to ensure the conservation of all populations and the ecosystem of which they are a part; and monitoring the status of each population or species that could be directly or indirectly affected by harvesting and/or associated activities.

The discussion of functions and organizational structure of the regime on page 2 should also be expanded to provide a clear exposition of responsibilities, relationships between the plenary body and that body or bodies providing scientific advice, and the type of relationships to be established with international bodies that deal with marine living resources of the Antarctic, including a discussion of the relative contributions that each body might make, how they would interact, and the relative distance of each from political influence.

Implicit in the discussion of the proposed action, and perhaps its greatest weakness, is the assumption that existing knowledge is adequate to implement a meaningful conservation regime allowing for substantial exploitation. The fact is that current information is not adequate to serve as the basis for reliable predictions concerning the impacts of substantial exploitation and that reliable information must be obtained and analyzed prior to substantial exploitation in order to avoid adverse environmental impacts. In light of the uncertainties and associated risks, the discussion here and elsewhere should be expanded to consider the desirability of a regime designed to provide the information needed for conservation of the resources, while permitting effectively controlled, experimental harvesting in conjunction with the mandatory collection of needed data. Under this approach, discussed below, fishery development would be initially designed and conducted as a controlled experiment, one of the major objectives of which would be to develop an adequate body of information for management decisions.

## Alternatives to the Proposed Action

As a preliminary comment, the proposed action should be fully described and discussed in the preceding section and should not be included in this section as an "alternative". Although this is a minor point, it reflects a recurrent problem with the DEIS -- the discussion is poorly organized and it is very difficult for the reader to gain an understanding of exactly what is proposed, how it differs from potential alternatives, why it has been chosen, and what environmental impacts will result. Moreover, there is at least one additional option which merits serious consideration and will be discussed below. The discussion should be expanded to include consideration of this alternative course of action.

The discussion of the alternatives that are identified should also be expanded and the apparently factual statements in the discussion which are based upon assumptions and conjecture, rather than data, should be identified as such. For example, there should be, as an integral part of the discussion of alternatives, a full discussion of the biological uncertainties and risks associated with any substantial exploitation activities inasmuch as it is these uncertainties and risks that must shape the development of a convention if it is to be meaningful.

The discussion of alternative 4, "Negotiation of an international agreement establishing a complete conservation regime", should be expanded. The discussion of the first 7 sub-option on page 6 is based upon the tenuous assumption that technological and other limitations will ensure low harvesting levels for the next several years. Inasmuch as it may well be two, five, or even more years before the regime enters into force, it is not at all clear that these factors will serve to effectively limit exploitation in the interim. Although the DEIS suggests that available technology is presently insufficient to overexploit living resources of the Southern Ocean, it appears that a number of countries are technologically capable of overexploitation of certain of these resources now, and this should at least be acknowledged in the discussion.

Although there may be some basis for preferring the second sub-option, the discussion fails to explain the basis or mechanism for increasing quotas by "fixed annual percentage increases over a fixed and limited period of years." Given 8 the fact that generation time of Euphausia superba is two to four years, and that the generation time for pinnipeds and whales may be on the order of six to ten years, one can assume that it would be difficult to detect cause-effect relationships in such a short period. Therefore, on biological grounds, it may well be more sensible to phase increases at five year intervals or longer. Perhaps more importantly, the discussion on page 6 assumes that available information is adequate to develop "interim limitations" to "minimize any possible adverse impacts". The discussion in the DEIS provides no support for this assumption and no indication of how this information would be obtained and applied. Unless the details of this sub-option are clearly set forth, there is no way to evaluate its merits. Meaningful quotas, regulations, and/or guidelines cannot be developed until available information and options have been critically evaluated. At a minimum, the DEIS should

at least set forth those parameters it would propose for determining the maximum harvest (for krill) that would have no long-term effect on either the ecosystem or its component populations.

As noted above, the statement on page 6 that "the first of these sub-options would likely provide the necessary margin of safety..." is not true. Furthermore, the second sub-option, although more appealing, may well not be preferable to other options discussed below.

The discussion of Alternative E should be strengthened by a more detailed discussion of the two options contained therein. In addition, it should be noted that the discussion of the option on page 7 admits that there is insufficient information upon which to base specific conservation measures. This statement applies to all the options discussed and would appear to support consideration of the additional alternatives discussed below. The last paragraph of this section on page 8 might better be reworded to reflect the fact that if a conservation regime is to be effective, it must include all states engaged in harvesting. It should, however, also reflect the obvious fact that full participation in a regime is effective in securing the conservation of the living resources only to the extent that the regime, itself, is effective.

The discussion of Alternative F should acknowledge that a prohibition on all harvesting of living resources 9 may not offer the maximum degree of protection to the Southern Ocean ecosystem unless it is coupled with similar constraints on the exploitation of non-living resources. Such exploitation of non-living resources will, of course, affect living resources under any of the options discussed, 10 and the DEIS should address this problem. Furthermore, while it is probably true that total protection cannot be attained, the DEIS should fully discuss the values to be gained by a conservation regime that makes provision for identifying and protecting areas of special biological significance such as breeding areas, feeding areas, and migratory paths. Finally, although the DEIS can probably not reveal all of the various considerations relevant to negotiating strategy and the likelihood of success of one or another option, the bald statements that states interested in commercial harvesting would have no incentive to accept this alternative and that it is an unobtainable alternative should be supported with some discussion. Here and elsewhere, the DEIS should set forth what is known of the intentions of nations with respect to harvesting and their technological capabilities.

In the discussion of the "Area covered by the regime", two alternatives are set forth. The discussion of the first alternative, limiting the area to south of 60° S, should be modified to more clearly articulate the reasons, of which there are many, for its unacceptability. The discussion in later sections of the DEIS provides numerous examples of resources that would not be protected. The second possibility, areas south of the Convergence, should be more fully discussed in terms of what would and would not be included thereby. A third alternative, defining the species of the Antarctic ecosystem to be covered by the agreement and applying the agreed upon conservation measures to those species, merits serious discussion in the DEIS. Biologically, this alternative may well be preferable to the others. Since the Convergence is not fixed, it may be difficult to enforce regulations which rely upon the Convergence as the definitive boundary, and the desirability of establishing an arbitrary geographic line that approximates the Convergence and includes a "buffer zone" for practical management purposes should be discussed. The last sentence in the discussion on
11 page 9 sets forth a weak reason for not considering this approach. Would it not be possible to specifically exempt certain species which are not part of the Antarctic ecosystem from the provisions of the convention? The DEIS should identify and discuss those species that are part of the Antarctic marine ecosystem but may at times range north of the Convergence.

## Additional Alternative Course of Action

As mentioned earlier, the discussion of alternatives should be expanded to include consideraton of at least one additional alternative that may well be preferable to the proposed federal action.

The suggested additional alternative is based upon the premises that: 1) any substantial harvesting will affect target species, associated species, and the ecosystem to some extent; 2) knowledge of populations and the ecosystem is inadequate to reliably predict and assess the impact of substantial harvesting at this time; and 3) data must be gathered and analyzed in order to assess the impacts of substantial harvesting before it causes adverse impacts. Given these basic considerations, the DEIS should be expanded to include a detailed discussion of an alternative course of action that would seek to negotiate a conservation regime pursuant to which:

1) harvesting in the immediate future would be limited to those levels, areas, and species which are considered by the appropriate scientific body to be such that they will not cause any irreversible changes in ecosystem structure, species composition, or relative abundance of the target or associated species;

2) harvesting in the immediate future would be limited and designed as part of a scientific research program designed or approved by the appropriate scientific body so as to provide needed data on the impacts of harvesting on target species, associated species, and the ecosystem. To evaluate harvesting impacts, such research harvests would include the requirement to gather and analyze baseline data on populations in both experimental areas and in such "control" areas as may be designated by the scientific body;

3) exploitation and taking for research would be limited to those levels, areas, and species determined by the scientific body to be appropriate, until the commission or such body as may be established, based upon the recommendations of the scientific body, is assured that any increase in proposed harvest:

a) will not reduce the target species to a level at which it ceases to play a significant functional role in the ecosystem and certainly not below the level at which it is capable of maximum net productivity (MNP), calculated with reference to the initial (unexploited) population size;

b) will not result in ecosystem changes which might impair the ability of a target species to recover to its initial (unexploited) size and distribution. (For example, exploitation of a target species such as krill could give an associated species a competitive advantage which could lead to ecological replacement and a permanent change in ecosystem structure. Krill must not be harvested down to a level at which such replacement could occur, precluding its recovery to present size, distribution, and functional role in the ecosystem. This lower bound, below which the population could not be reduced, may be significantly higher than the MNP point and, if so, this test would prevail over MNP to determine the lower bound); and

c) will not cause populations or associated species, as a result of harvesting the target species, to decline below the levels at which they are capable of maximum net productivity, calculated with reference to initial (unexploited) population size, or below levels from which they can recover to present population size, distribution, and functional role in the ecosystem. (As in (b) above, the test which results in requiring the highest population controls and serves as the lower bound below which no harvest would be permitted to reduce target or associated species.);

4) the commission or such body as may be established would be required to base its determinations with respect to the criteria set forth in (3) upon the advice of the appropriate scientific body; and

5) it would be required that the scientific body be provided with sufficient data and analyses by the party proposing exploitation to provide a basis for assurance that the criteria set forth in (3) will be satisfied. Proposed harvests would not be permitted if the available data were inadequate to provide necessary assurances. Such a requirement would appropriately place the burden for justification of exploitation upon those seeking to exploit rather than upon the commission to prove that such exploitation would cause an adverse effect.

The discussion of this suggested alternative and the others identified in the DEIS should also include an evaluation of the desirability of a number of options relating to organization, liaison with other organizations, and sanctions which are not addressed in the DEIS.

For example, the discussion should include consideration of the desirability of including a provision in the proposed convention that would constitute an undertaking by all signatories to ban trade (in either all subjects or just fish and fish products, or some mix of the two) with non-member nations who are exploiting Antarctic living marine resources. The discussion should note that the Pelly Amendment has been interpreted in the context of the International Whaling Commission to apply to non-member nations who whale outside the International Whaling Commission and that it is likely that the United States would interpret the Pelly Amendment to also apply to non-member countries who exploit Antarctic resources in a manner that diminishes the effectiveness of the conservation program established by the proposed convention.

For similar reasons, the discussion should include
consideration of the desirability of including provisions
in the convention that would constitute an undertaking by
all signatories to join, continue membership in, or comply
with conservation measures of the International Whaling
Commission and such body as may be established pursuant to
the Convention for the Conservation of Antarctic Seals.
Statements in the DEIS that whaling and sealing are
regulated by these Conventions ignore the fact that an
effective conservation regime cannot be achieved unless all
12 parties to the proposed convention are in full compliance
with the conservation measures established under the other
Conventions.

Discussion should also be devoted to consideration of mechanisms that might be established to ensure that proposals for the exploitation of non-living resources come before the commission or such body as may be established for review and consideration in consultation with the scientific advisory body, of the potential impacts of such exploitation before it is undertaken.

The discussion should also be expanded to include consideration of the desirability of providing for mandatory observer exchange and for complete freedom to inspect vessels engaged in either exploitation or processing of living resources. The discussion should also include consideration of the desirability of providing for inspection of land stations engaged in processing or other support activities inasmuch as their impact upon the ecosystem and some of its component species could be great.

As a last point on additional alternatives for considera-
13 tion, the DEIS should discuss in detail the mechanisms that
would be appropriate for ensuring that harvesting, prior to
the regime's entering into effect, will be carried out in
accordance with the soundest scientific advice of an apolitical
nature. With this in mind, it would be appropriate to in-
clude a discussion of the advisability of formally inviting
the Scientific Committee on Antarctic Research (SCAR), a
body of the International Council of Scientific Unions to
undertake to provide advice.

## Relationship of the Proposed Federal Action to International Agreements with Implications for the Antarctic Environment

The discussion in the DEIS fails to address the relationship of the proposed federal action to domestic statutes such as the Marine Mammal Protection Act of 1972 and the Endangered Species Act of 1973. Inasmuch as both statutes contain provisions that relate to international aspects of conservation and establish certain goals for negotiation of international agreements, a detailed discussion is appropriate -- either in this or another section.

### Agreements Pertaining to the Antarctic Region

This section of the DEIS should be expanded to include a discussion of the significant provisions of the International Convention for the Regulation of Whaling and Schedule appended thereto, the Convention for the Conservation of Antarctic Seals, and other appropriate international agreements. It should also be noted that the Convention for the Conservation of Antarctic Seals is now in force. In the last paragraph of this section, it should be noted that the Convention on International Trade in Endangered Species of Wild Fauna and Flora applies only to trade, not harvesting.

### Agreements Pertaining to the Marine Environment

The DEIS should discuss relevant provisions of each of the conventions cited. As the discussion presently stands, there is no way of telling what advantage might be taken of the existing body of international law either by reference in a convention or otherwise to further protect and conserve the living resources of the Southern Ocean. The last paragraph of this discussion might be an appropriate place to discuss problems caused by non-member (for example, a non-IWC member) nations harvesting species or populations covered by the convention in question. A discussion of this problem and the importance of requiring parties to the proposed convention to join and/or comply with the conservation measures, including the imposition of sanctions, or other conventions should be included here or reference should be made to another section where it is discussed.

### Fisheries Bodies

A basic weakness of the DEIS, is that the discussions often appear to stress the development of an international fishery regime in the Southern Ocean rather than the development of a conservation regime for the Southern Ocean ecosystem. Since the proposed action is that a conservation, not a fisheries, agreement be concluded, would it not be appropriate to include a detailed discussion of

the importance and value of establishing close ties with
14 international conservation bodies, such as the International
Union for the Conservation of Nature and Natural Resources
(IUCN), as well as fisheries bodies.

### Description of the Environment

This section should be expanded to effectively identify
uncertainties and to stress that many "estimates" are based
primarily upon assumption and conjecture. Throughout this
15 section and in other appropriate parts of the DEIS, it
should be stressed that little is known about various popula-
tion parameters and the physical and/or biological factors
regulating their distribution and abundance. Unless these
uncertainties and associated risks are straightforwardly
addressed and considered, whatever federal action is under-
taken will probably provide insufficient safeguards.

In the third full paragraph on page 17, the DEIS
correctly suggests that the present biological knowledge of
populations is either "not well known" or "virtually un-
16 known". Statements such as this are supportive of the idea
that interim conservation measures, other than a strictly
controlled harvest as a part of a research effort, cannot
be shown to be the alternative of choice. The DEIS question-
ably excludes whales from those species about which little
is known, and the discussion should be expanded to make it
clear that although some estimates are available and informa-
tion is relatively better for whales than for some other
components of the Antarctic ecosystem, present knowledge is
not sufficient and should not serve as the standard.

On page 17 and elsewhere of the text, the discussion of krill standing stock estimates should be expanded to make it clear that these estimates vary so widely because they are based, in part, upon conjecture and assumptions rather than hard data.

The discussion of squid, fish, and birds could all be usefully expanded to more fully elucidate their roles in the Southern Ocean ecosystem.

In the discussion of seals on pages 21-22, it would
17 be correct to say that the crabeater seal is the most
abundant seal in the world. The Weddell is not a pack-ice
seal, but rather is found in coastal areas of fast ice.

With reference to the discussion of whales on page 22,
18 the first paragraph should be supported by references.

19 In connection with the last paragraph in this section, the DEIS might usefully discuss the possibility that populations at lower levels and higher growth rates are apt to consume more food (energy) in order to sustain and fuel that growth than would be the case with older animals. If this is so, the need for krill among growing populations may be greater, at some point, than the stable populations in the past and the importance of this possibility, in terms of krill conservation, should be considered. The discussion in the DEIS should be expanded to reflect the possibility that there is, in fact, no significant "sustainable yield" of krill which can be harvested without adversely affecting the whales.

### Food Web

20 Under the discussion of "food web" on page 22, the DEIS says that because of their abundance, krill dominate the zooplankton. This statement is a tautology but does not explain the dominance. It would be more appropriate and accurate to simply say that they are more abundant and that scientists are not sure why.

The first full paragraph on page 23 states that "...predators divide up the available resource by feeding in different geographic regions, at different times of the year, and on different size classes of krill." The DEIS should provide a citation of authority for this statement.

21 The second full paragraph on page 23 refers to estimated annual total production. The figure given as 340 million tons, almost double the earlier low estimate given in the DEIS of 180 million tons (page 17). As mentioned earlier, the DEIS should be expanded to include a detailed discussion of the range of estimates and the uncertainties inherent therein. The importance of this discussion is obvious in that it bears directly on the question of how much, if any, krill can be taken as "surplus" without affecting the balance of the ecosystem.

22 The "food web" discussion should be substantially expanded to address alternate food paths and the possibility of substantial ecosystem changes that might result from the emergence of an alternate path as a consequence of krill harvesting.

### Areas of Special Biological Importance

23 The discussion in the DEIS of areas of special biological importance should be greatly strengthened by the inclusion of discussions of specifics. One can assume that each species and its component populations have areas of special biological importance for purposes of breeding, feeding, resting, and/or migration. It logically follows that there are many areas other than the Scotia Sea and waters off the island groups that are critical. For example, coastal fast ice areas where there are perennial tide cracks are of special biological importance to the Weddell seal. Many, if not all, of the sub-Antarctic islands have unique flora and fauna, and these communities should be protected from the adverse impacts of man's activities including those which might be associated with the exploitation of living resources of the Southern Ocean. The section should be revised and expanded to clearly identify the present state of knowledge and the need for studies to identify areas of special biological importance to the species and populations which are components of the Antarctic marine ecosystem.

24 Figure 2 is inaccurate in many respects and in need of substantial revision. Quite aside from gross and inadvertent errors such as that which implies that six species of Antarctic pinnipeds feed on crabeater seals, it is in need of revision so as to more accurately portray the ecosystem as a whole.

### History of Commercial Harvesting

This section of the DEIS warrants careful revision and expansion. As examples, the discussion of whaling should note that only whaling activities of IWC member nations are regulated under that Convention. Although it is implied, it should be specifically stated that populations of whales have been significantly reduced because of lack of regulation.

25 In the section on seals, the DEIS indicates that fur seals were harvested for oil when they were, in fact, harvested for hides. It is not true that elephant seal harvesting became unprofitable before populations were reduced to a "critical" level. The last sentence should be corrected to read "There is now no commercial harvest of fur seals or elephant seals south of 60° S."

The section on fish should be strengthened by the addition of a map showing the FAO statistical areas. With reference to the fourth paragraph on page 26, what other conclusion can be reached than that the stocks have been overexploited?

With reference to krill, the discussion on page 26 suggests that "...because of the decline of their major predators, baleen whales, krill have been receiving increasing international interest as a potentially harvestable resource...". The discussion should be expanded to explain the causal relationship that is suggested.

26 Although it may be true, as stated on page 26, that "the present total catch is 20,000 to 40,000 tons, an insignificant amount in comparison with krill standing stock", it would be better, in light of the gross uncertainties, to rephrase the sentence to read: "The present total catch in 1976-77 was estimated to be between 20,000 to 40,000 tons, which is less than one tenth of one percent of present standing stock estimates."

The first sentence on page 27 should be rephrased to read: "The only krill species of commercial interest, at this time, is Euphausia superba.", and it would be appropriate to insert between sentences 3 and 4: "As markets develop, economic incentives will increase, and the fishery can be expected to expand rapidly." If more evidence is needed as to the inadequacy of the information available and the consequent need for an extremely conservative approach, the last sentence in this first paragraph provides it.

In the discussion of penguins, a reference should be provided for the first statement in this section. It would be useful to separate the third paragraph on page 27 from the discussion of penguins in some way so as to set it off as a concluding paragraph to the entire section on harvesting. The implication in this paragraph that commercial harvesting, when controlled as an experiment, can provide a great deal of information about the Antarctic ecosystem should be fully discussed here and in the alternatives section.

## Scientific Investigation

27 The first sentence of this section appears to disregard the fact that a great deal of research was done before the Antarctic Treaty was either considered or came into existence. The paragraph is too superficial to be meaningful, and the objective of including it is unclear. The discussion could, however, be usefully expanded to include a discussion of relevant on-going research as well as perceived needs.

## Shipping Traffic

The discussion should be strengthened to include specific information on shipping traffic (by vessel type, routes, numbers of voyages, etc.) in different areas of the Southern Ocean. Such data on existing shipping, coupled with projected shipping activities (either in this section or elsewhere), are vital to developing an understanding of potential impacts not only of vessels at sea, but on the Continent, its adjacent islands, and the sub-Antarctic islands. Such information would also be useful for determining how research might be planned to take advantage of present shipping routes.

## Ecosystem Responses to Disturbance

The last sentence of this section on page 28 makes a valid point which is supportive of the suggested alternative and which merits expanded discussion here and elsewhere in the DEIS.

## Potentially Harvestable Resources

28 The discussion in this section should be expanded to recognize that macro-algae, shellfish, and even phytoplankton could be "harvestable resources", at some point. The statement on page 28 that "all of the others depend on krill as their main food supply" is incorrect. Since so little is known about alternative prey species and whether predators can or will switch to alternatives, the statement that "fluctuations in the size of krill populations will be reflected in the populations of its predators" would be better worded: "fluctuations in the relative abundance and/or availability of krill likely will affect the distribution, abundance, and/or productivity of species which are directly or indirectly dependent upon krill as a food source."

This section reflects the confusion and uncertainty characterizing the entire discussion. The DEIS should straightforwardly address the question as to whether or not there is adequate information at this time to predict impacts and, if not, when such information will be available. If information is not adequate at the present time, the DEIS should set forth a rational explanation as to why it is appropriate to proceed with an action, as is proposed, that would allow harvesting, other than as a part of a research experiment, in the absence of adequate information.

## Environmental Impacts of Proposed Action and Alternatives

As a general comment, this section of the DEIS is less valuable than it should be inasmuch as the objective of identifying and quantifying environmental impacts of the proposed action is exceedingly difficult to achieve since the specifics of the proposed action are not provided so as to allow such determinations to be made.

29 The discussion of types of impacts might be usefully expanded through, for example, discussion of such impacts of direct harvesting as, in addition to standing stock reduction, changes in growth rates, reproductive rates, and the age-sex composition of harvested populations. The discussion of indirect impacts should be expanded to include not only the effect of decreased abundance, but changes in distribution, productivity, and/or behavior of prey species, e.g. krill swarming behavior.

The DEIS should include a full discussion of the possibilities of a krill fishery leading to ecological replacements and/or the establishment of an alternative food chain, as earlier mentioned. For example, a phytoplankton-krill-fish/seal/bird/whale/man food chain may very well shift to a phytoplankton-copepod-myctophid-squid/fish food chain which could be very resistant to the recovery of krill.

As the DEIS notes, harvesting would result in increased shipping, and possibly the development of processing plants and support bases on the continent proper, adjacent islands, and certain sub-Antarctic islands. These activities could result not only in environmental pollution but the disturbance and destruction of habitat for shore breeding species of birds and seals, and the DEIS should address these considerations more thoroughly than is done in part 4 of this section on pages 38 and 39.

Although the last two sentences of the introduction to this section, on page 30, state that the range of possible impacts will be compared and discussed, subsequent discussions provide little in addition to that presented earlier.

### Concepts Underlying the Proposed Action

Consideration should be given to placing this portion of the DEIS in a section entitled "Rationale for the Proposed Federal Action".

### Health of the Ecosystem

To be useful, terms such as "health of the ecosystem", "overall productivity", "robust condition", "marginal levels", "good estimates", and "biology of the system" must be defined.

As discussed elsewhere in these comments, the DEIS must include a discussion of conservation principles and standards to be sought if discussions such as that in this section are to be meaningful.

### Conservation Objectives

Careful consideration should be given to the revision of the first three sentences in the last paragraph on page 31. The first sentence admits that understanding is incomplete; the second sentence says that whale populations are best known; and the third sentence describes the estimates of whale abundance, growth, reproduction, and mortality as good estimates of these biological parameters of the harvested species. The third statement is not accurate and, furthermore, the three sentences, when taken together, may erroneously imply that current knowledge of whale populations either could or should be used as a standard for the development of information on other populations. The discussion should be expanded to make it clear that this is not the case.

Much of the discussion on page 32 might well be placed in the section describing the environment rather than in a description of conservation objectives. It is not self-evident that "the proposed Federal action would require that data from commercial harvesting be both collected and analyzed". The statement on page 1 of the DEIS is that the regime "would need to provide for" data acquisition, but does not set it forth as a requirement. Furthermore, requirements simply to collect data without a clear description of those data could lead to the collection of data other than those that are most useful. The comments on the potential for overexploitation of fish, seal, and krill do not appear to be consistent with statements found earlier in the DEIS on exploitation. In the last sentence of the fifth full paragraph on page 32, and most certainly in the last paragraph of this discussion, there is, again, the disturbing suggestion that an objective is to accommodate conservation measures to a harvesting regime rather than accommodate harvesting strategies to a conservation regime.

### Management Options

It is over-simplification to state: "It is possible to undertake an ecosystem level approach to resource management in the Antarctic because the ecosystem is relatively simple and the food relationships and interactions among species are understood." Although the ecosystem may be comparatively simple, food relationships and interactions among species certainly are not well understood, and the DEIS should not convey an over-simplified view of the Antarctic vis-a-vis its potential for "ecosystem management."

### Impacts of Commercial Harvesting

### Impacts Unaffected by the Proposed Action

The DEIS fails to take into account that the International Convention for the Regulation of Whaling applies to only those countries that are signatory to it and agree to comply with its regulations. It would be appropriate, in this section and elsewhere, to discuss the advisability of requiring that a country, signatory to the proposed convention but not to the IWC, that is engaged in whale or krill exploitation in the Southern Ocean, at least comply with the conservation measures of the IWC if not become a party to the Convention proper.

### Direct Impacts on Exploited Stocks

As noted earlier in these comments, the DEIS should contain a full and careful discussion of estimates of krill abundance, and the introduction of another estimate further supports this suggestion. The third paragrph notes that "a potential for an enthusiastic unregulated harvest to overexploit the krill population is real," while the fourth paragraph states that "probably within ten years, and almost certainly within twenty years, a capability for over-exploiting krill will exist." The DEIS should include a detailed discussion of what may happen in terms of world fishing fleet mobilization should processing problems be solved and market acceptance of the product be altered. A careful discussion may well lead one to conclude that an estimate of 10 years is overly optimistic.

### Indirect Impacts on Dependent Species

The DEIS should be corrected to reflect the fact that crabeater seals are not likely to be affected by a krill harvest simply because they are very abundant.

### Local Impacts of Harvesting Operations

As noted elsewhere in these comments, the DEIS needs to be substantially strengthened in terms of estimating krill harvest impacts on the area in which either harvesting, processing, or support activities (fueling facilities, provisioning facilities, land-based storage and/or refrigeration facilities, etc.) take place. Such activities might well lead to major alterations in the ecosystem, particularly on and around a number of the sub-Antarctic islands critical to marine mammal, as well as other, populations.

### Disturbance of Marine Ecosystem

The DEIS should include a substantive discussion of the importance of the scientific and aesthetic, as well as consumptive, values of the Antarctic ecosystem. Although alluded to in this section, the discussion should be expanded.

The discussion in the last paragraph on page 39 again points out the importance that might be attached to a "carefully controlled harvest of various species with good monitoring and data reporting" which could "provide an opportunity for a contolled experiment on the Antarctic marine ecosystem". As noted earlier, the DEIS would be substantially strengthened by a careful discussion of the desirability of combining limited initial harvesting with a carefully designed and controlled scientific experiment.

### Environmental Impacts of Proposed Federal Action and Alternatives

As noted earlier, the discussion of the proposed Federal action and alternatives should be significantly expanded by the addition of at least one more alternative for consideration and such expansion would require changes in this section. As a general matter, it is worth noting once again that in considering alternatives, the DEIS should address potential adverse impacts resulting from exploitation of non-living resources to develop means whereby it can be assured that proposed actions will be reviewed by the commission and its scientific advisory body with respect to living organisms.

Much of the information in this section is redundant. and comments will be limited.

The table on page 43 suggests that the Federal action proposed in the DEIS will provide for both adequate conservation measures and enforcement of those measures. As stated elsewhere, the proposed Federal action is not discussed in sufficient detail to provide such assurances inasmuch as, among other things, no standard by which to manage is put forward. The DEIS should be expanded, particularly on pages 53, 54, and 55, to provide for fuller discussion of the "complete conservation regime" and the "conservation regime with specific conservation measures or interim harvesting moratorium" as well as a full discussion of the suggested additional alternative discussed earlier in these comments.

## Short vs. Long Term Productivity

This brief discussion once again highlights two weaknesses in the DEIS: discussions are oriented towards the development of a fisheries regime rather than a conservation regime, and the management standard is not articulated.

## Commitment of Resources

The DEIS discussion should be rephrased in the fourth paragraph to reflect the fact that only an agreement on strict controls with provision for enforcement will ensure that the impact of interim harvesting is minimal. There is no reason to believe that technical and economic considerations, given the amount of time that may elapse before a regime comes into force, will act as sufficient deterrents to prevent overexploitation.

## Conclusions

The DEIS should be substantially revised to reflect the comments set forth above. Of particular importance is the expansion of the DEIS to include a discussion of other alternatives and the results of the recent meeting in Australia which may lead to the conclusion that the presently proposed Federal action is not the preferred course of action.

Sincerely,

John R. Twiss, Jr.
Executive Director

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NATIONAL SCIENCE FOUNDATION
WASHINGTON D C 20550

OFFICE OF THE
ASSISTANT DIRECTOR
FOR ASTRONOMICAL,
ATMOSPHERIC, EARTH,
AND OCEAN SCIENCES

Mr. William Mansfield, III
Office of Environmental Affairs
Department of State
Washington, D.C. 20520

Dear Mr. Mansfield:

The National Science Foundation has reviewed the Department of State's "Draft Environmental Impact Statement for a Possible Regime for Conservation of Antarctic Living Marine Resources" (EIS) dated February 1, 1978. The Foundation's comments are based on general agency interest, specific interest as manager of U.S. activities in Antarctica, and upon agency responsibilities as a member of the Antarctic Policy Group (APG).

The EIS, together with its appendices, documents the clear inadequacy of fundamental scientific knowledge about the antarctic ecosystem and fairly reflects the divergency of opinion found in the scientific literature. The EIS properly notes the central importance to conservation of more reliably determining the level of primary productivity in the Southern Ocean and the consequent need for fundamental research on the physical, chemical, geophysical and biological processes in the Southern Ocean.

The EIS offers persuasive evidence that commercial harvesting of antarctic living marine resources is an immediate probability, and rightly concludes that commercial harvesting could possibly attain levels that threaten the antarctic ecosystem in the near future. The EIS discusses a full range of possible Federal actions through six specific proposals; the discussion content fully justifies the choice of option four, "Negotiation of an International Agreement Establishing a Complete Conservation Regime" as the proposed Federal Action.

The EIS lists five provisions necessary to accomplish the purposes of the conservation regime. The Foundation recognizes that this is not an exhaustive listing, and that specific details must be worked out in the course of international negotiations. A continuing broad public participation will reenforce the conservation commitment while negotiating essential fishery provisions. The Departments' initiative to include public representation in the U.S. delegation to these negotiations is a welcome means of preserving the intended principles and purposes of the proposed regime.

The Foundation appreciates this opportunity to comment on the EIS because it speaks directly to three primary responsibilities of the Foundation: pursuit of scientific knowledge, management of the U.S. Antarctic Program, and participation in the Antarctic Policy Group. The Foundation supports and endorses the Proposed Federal Action.

Sincerely yours,

John B. Slaughter
John B. Slaughter
Assistant Director

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DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

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15 MAR 1978

Mr. William H. Mansfield III
Office of Environmental Affairs, Room 7820
Department of State
Washington, D.C. 20520

Dear Mr. Mansfield:

Appropriate staff and operating elements of the U. S. Coast Guard have reviewed the Draft Environmental Impact Statement for a Possible Regime for Conservation of Antarctic Living Marine Resources and offer the following comments.

30 1. Page 10. paragraph III. B. Agreements Pertaining to the Marine Environment. The second sentence should be rewritten, "The International Convention for the Prevention of Pollution of the Sea by Oil, 1954, as amended in 1962 and 1969. (Entry into force 20 January 1978)."

2. The Coast Guard should be kept informed of all developments regarding enforcement of any agreements entered.

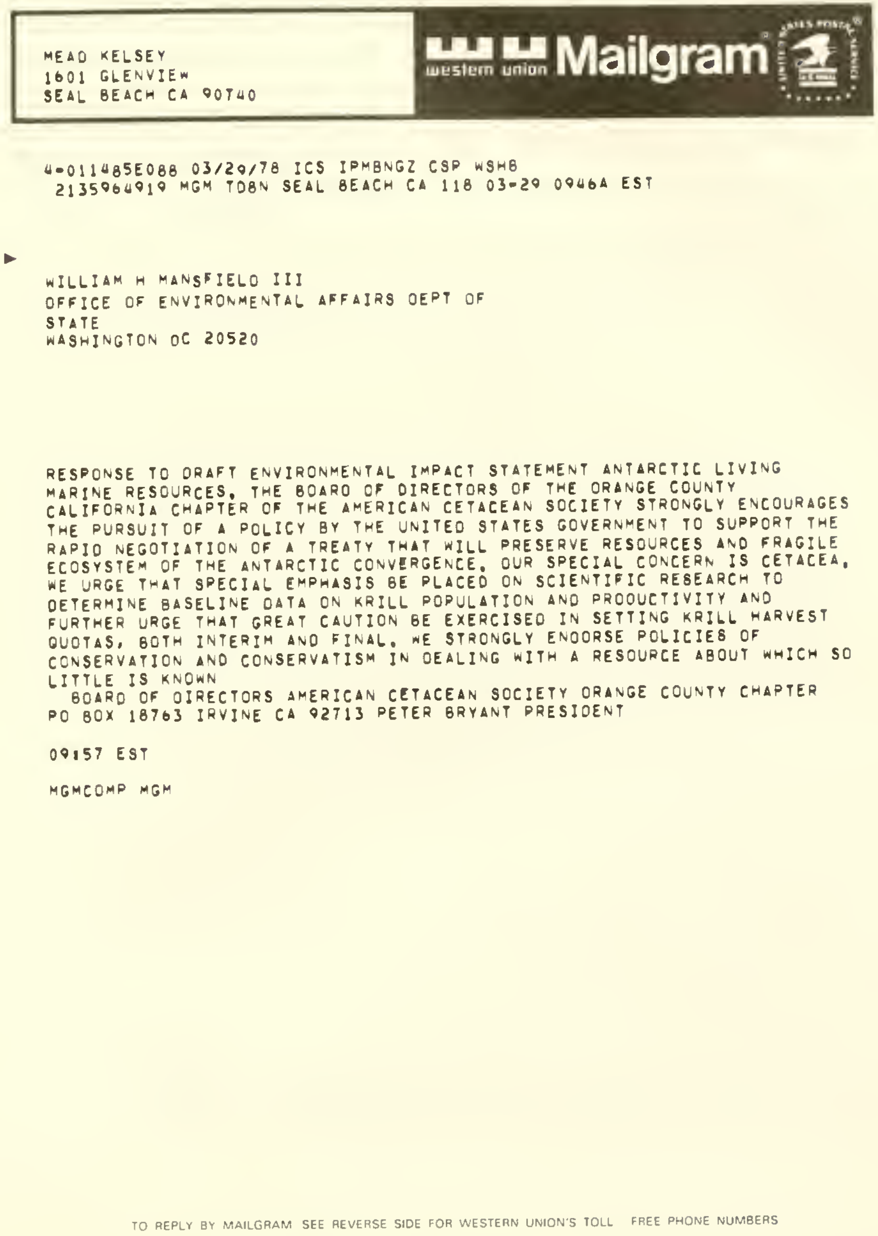
The Coast Guard has no further comments to offer at this time, nor do we have any objections to the proposal.

The opportunity to review this draft statement is appreciated.

Sincerely,

R. S. PALMER JR
Commander, U.S. Coast Guard
[illegible] Environmental
Protection Division
By direction of the Commandant

# COMMENTS ON THE
# DRAFT ENVIRONMENTAL IMPACT STATEMENT
# BY
# NON-GOVERNMENTAL ORGANIZATIONS



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WILLIAM H MANSFIELD III
OFFICE OF ENVIRONMENTAL AFFAIRS DEPT OF
STATE
WASHINGTON DC 20520

RESPONSE TO DRAFT ENVIRONMENTAL IMPACT STATEMENT ANTARCTIC LIVING MARINE RESOURCES, THE BOARD OF DIRECTORS OF THE ORANGE COUNTY CALIFORNIA CHAPTER OF THE AMERICAN CETACEAN SOCIETY STRONGLY ENCOURAGES THE PURSUIT OF A POLICY BY THE UNITED STATES GOVERNMENT TO SUPPORT THE RAPID NEGOTIATION OF A TREATY THAT WILL PRESERVE RESOURCES AND FRAGILE ECOSYSTEM OF THE ANTARCTIC CONVERGENCE, OUR SPECIAL CONCERN IS CETACEA, WE URGE THAT SPECIAL EMPHASIS BE PLACED ON SCIENTIFIC RESEARCH TO DETERMINE BASELINE DATA ON KRILL POPULATION AND PRODUCTIVITY AND FURTHER URGE THAT GREAT CAUTION BE EXERCISED IN SETTING KRILL HARVEST QUOTAS, BOTH INTERIM AND FINAL, WE STRONGLY ENDORSE POLICIES OF CONSERVATION AND CONSERVATISM IN DEALING WITH A RESOURCE ABOUT WHICH SO LITTLE IS KNOWN

BOARD OF DIRECTORS AMERICAN CETACEAN SOCIETY ORANGE COUNTY CHAPTER
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March 20, 1978

Mr. William H. Mansfield
Office of Environmental Affairs
Department of State
Room 7820
Washington, DC 20520

Dear Mr. Mansfield:

On February 1, 1978, your office made available to the public a draft Environmental Impact Statement for a Possible Regime for Conservation of Antarctic Living Marine Resources. At that time, you solicited from the public both oral and written comments on the draft EIS. The Center participated in the public meeting held by the State Department on February 10 for oral comment on the draft EIS, and we are writing this letter to provide you with a written version of our thoughts on that draft.

We submit these comments on behalf of the four cosignatories to this letter. We know that you will give these comments thoughtful consideration, and we hope that they are useful to the State Department as it prepares for the decisive living resources regime session.

Our first comment on the draft EIS is a congratulatory one. We perceive in this draft EIS a genuine effort on the part of the State Department to comply with the National Environmental Policy Act. In our dealings with your office and with Ambassador Brewster and his staff, we have found you to be helpful and open to our suggestions. We sincerely hope that this experience will be replicated in the case of future State Department proposals for action which may significantly affect the quality of the human environment.

Despite our overall approval of the draft EIS we cannot say that we find it wholly satisfactory. It suffers from procedural and substantive defects which impair its effectiveness as a guardian of the environmental soundness of federal actions. We shall devote the remainder of this letter to a discussion of the three most serious substantive defects in the draft and of the two most damaging procedural defects in the way in which the draft was prepared and distributed.

The three serious shortcomings which we find in the draft EIS are as follows:

(1) The draft EIS is distressingly vague as to how the conservation regime which it envisions would work. It is clear from the draft that the regime under consideration will achieve the conservation of Antarctic living resources primarily by regulating which of these resources can be taken, and in what numbers, how, when, and where they can be taken. While we do not argue with the claim that conservation through management is politically attainable in a way that conservation through a moratorium is not, it is essential that the final EIS go into more detail on how the management system would work. In particular, it is important to establish how the proposed regime will differ from other fishery management systems such that this one succeeds where others have failed; viz., in preventing the gradual but eventual destruction of the managed stock despite the best efforts of the regulatory body to prevent that destruction. It is easy to say that we support an effective regime, but it is difficult to create one. This difficulty is increased by the fact that:

(a) We are dealing in resources whose numbers, life-cycle, swarming habits, breeding stocks, and interaction with other species are currently unknown to us;

(b) We are dealing with polar waters where there are fewer species than in temperate waters but large numbers of individuals in each species, so that damage to one species ramifies throughout the ecosystem more rapidly and more destructively than in temperate waters;

(c) No nation or group of nations is recognized by other nations as having exclusive economic control over the marine living resources of Antarctica, and fishery management schemes in no-owner situations are always more precarious than when one nation's control over the stock is recognized;

(d) The proposed regime would manage not a single species but the entire Antarctic marine biomass;

(e) It is possible that one of the resources which the regime would regulate (viz., krill) could become a major source of protein for a large fraction of the earth's human population.

These and other facts all make the regulatory body's task a formidable one. A weak regime or one that is not carefully articulated both with the existing species-specific conventions operative in the Southern Ocean and with existing international agencies concerned with the dietary needs of this planet's undernourished people is an invitation to political conflict and environmental degradation. It could damage the fragile peace among the Antarctic Treaty Consultative Parties and lessen the chances of success for similar regimes in other areas of international concern. On the other hand, an effective regulatory body, one that can both manage the Antarctic biomass effectively and integrate its activity with that of other international bodies, would be an environmental and political milestone deserving of full support from the United States Government and from the world environmental community. Our problem is that from reading the draft EIS we cannot tell which sort of regime, the albatross or the milestone, we are getting. We will be able to tell which it will be only when we know in more detail the power and limits, the nuts and bolts, of the regulatory system embodied in the regime.

We realize that the draft EIS was prepared early in the nego-
tiating process and that in any negotiating process flexibility as
to details is essential to a positive outcome. This need for flexi-
31 bility does not, however, warrant a vague and uninformative descrip-
tion of the proposed regime as we find in the draft EIS. If in
preparing the final EIS the State Department achieves the level of
specificity we have described here, it will have produced a document
that meets the requirements of the National Environmental Policy
Act, assists our negotiators in their efforts to get an environ-
mentally sound regime out of the decisive session, and contributes
to the common effort of all those nations interested in an effective
Antarctic living resources regime.

(2) The draft EIS so poses the options open to our negotiators that it invites an acceptance in fact of the very gradualism that it condemns. The draft EIS described a continuum of possible approaches to Antarctic marine living resources ranging from total inaction to a total ban on all harvesting in Antarctic waters. It locates the proposed federal action at a point on this continuum where a complete conservation regime with the machinery necessary to the achievement of its task is negotiated, but where interim catch limitations (under sub-option two) take the place of detailed conservation measures until the data base for such measures can be established. Insofar as the stricter alternatives (options 5 and 6) are likely to create opposition to the regime among exploiter states, and insofar as the paucity of data on the Antarctic biomass makes it impossible to establish scientifically defensible detailed conservation measures now, we support the selection of option four over the stricter options. But if the regime that purports to embody option four were to follow sub-option one and postpone the setting of interim catch limitations until technological improvements and market pressures required them, it would be a politically unwise and environmentally unsound regime. It would reflect a serious misunderstanding of the economic forces which make the negotiation of after-the-fact reduction of gear, effort,

area, season, age or size, species, or other limit on total catch
32 vastly more difficult than the negotiation of similar limits before
national fishing fleets are outfitted for massive Antarctic harvests.
It is, therefore, vitally important that in the final EIS the vastly
different environmental consequences of sub-options one and two in
alternative four be spelled out and the unacceptability of sub-option
33 one be stressed. Only if this is done can our fear that the excessive
gradualism condemned in the discussion of alternatives one through
three might infect the alternative for which our government has
opted be allayed.

(3) The draft EIS is singularly silent on what will be done with whatever living resources are harvested under the regime. We have heard the arguments in defense of this silence, and we are not convinced by them. We have been told that Third World nations are not currently demanding any share or krill or fish catches in Antarctic waters, that they will be happy with a regime that does not exclude them from membership if and when they decide to fish in those waters. We have been told that it is unseemly for the U.S., a non-exploiter of the resources which will be regulated by the regime, to tell exploiter states that they should share their catch with less developed nations. And we have been told that the time to work out distribution schemes has not yet come since we do not know as yet how much krill or other species can be harvested without serious harm to the Antarctic biomass and since we do not know as yet if krill will ever be useful, directly or indirectly, in meeting human protein needs. While there is some truth to each of these arguments, they do not justify the silence which is at issue here. Silence in this context as in so many other expresses a preference for a certain course of action as effectively as any words could. Silence about the interest of protein-deficient nations in krill harvests betokens our acceptance of a system that allocates whatever krill is harvested to those nations with the capital and technological capability to exploit the resource. Unless the world economic situation undergoes radical change soon, such a harvesting regime would exclude the most protein-deficient nations of the world from any share in the protein wealth of Antarctic waters beyond that which exploiter states in their largesse choose to give to them. This is surely not the way to keep Antarctic marine resources from becoming a source of international discord; it is in fact a formula for discord.

We realize that the State Department's NEPA obligation vis a vis the effect of the living resources regime on the protein needs of the less developed countries is different from its obligation vis a vis the effect of the regime on the Antarctic ecosystem. The latter is a direct and primary effect whereas the former is a secondary or indirect socio-economic effect. But both the CEQ Guidelines on the Preparation of Environmental Impact Statements (40 C.F.R. §1500) and the relevant case law (see McDowell v. Schlesinger, 404 F. Supp. 221 (W.D. Mo., 1975)) make it clear that secondary as well as primary consequences for the environment should be included in the analysis included in an EIS. Especially where the indirect socio-economic effect in question is the practical exclusion of the poorest nations of the world from access to Antarctic marine living resources and where this exclusion could exacerbate their chronic food problems and fuel their animosity towards the more developed nations, this effect should be studied and alternatives to it considered if the mandate of NEPA is to be fully respected.

We realize that it would be a serious error for this nation or the other nations of the world to think of krill or other polar protein sources as a panacea for the world hunger problem. We realize also that such panacea thinking would divert attention away from the changes in world economic structures which must be made if hunger is to be eliminated and would put pressure on the regime's regulatory body to permit ecologically unsound harvesting of Antarctic marine living resources. But while krill is not a panacea and while treating it as one would be mistaken, it remains true that at some time in the future a carefully managed Antarctic biomass may play an important role in solving the world hunger problem. The Consultative Parties would therefore be acting in their own long-term self-interest and in the interest of all mankind if they included in the
34 regime some provision for Third-World participation in the protein benefits involved in Antarctic resource harvesting. We suggest that provisionally at least this participation be ensured by making FAO a full partner in whatever regulatory body is finally established. In integrating FAO into the regime, the treaty parties should make explicit their understanding that this is being done with a veiw to the day when Antarctic living resources can be used to help meet the protein needs of the earth's human population. An EIS that was silent about this dimension of Antarctic living resources would fall short of the thoroughness required of such documents and comfort those who, for whatever reason, desire that those nations most in need of new sources of protein have the least access to whatever protein-rich foods can be taken from Antarctic waters without harming that ecosystem.

There are two serious procedural defects involved in this draft EIS. They are:

35 (1) The timing of the draft EIS relative to the State Department's decision process has frustrated the comment process mandated by NEPA and spelled out in the CEQ Guidelines. Our comments and those of other interested parties will be received after the Special Consultative Session at Canberra has prepared a draft for a Marine Living Resources Regime for Antarctica. It is therefore impossible for the comment process to have any effect on the initial negotiating position taken by our negotiators at Canberra. Yet it is that position which in all probability has established the environmental dimensions of the entire negotiating process. Had the draft EIS been prepared and circulated for comment in such a way that our comments on it would have been received prior to the Canberra

Session, the comment process would have had the effect it was meant to have by the Congress when it approved the National Environmental Policy Act. As things stand, that process has been largely frustrated and the State Department has made many decisions on a Marine Living Resources Regime without the benefit of written comment from the public.

We appreciate the fact that the timing of the Canberra Session was not wholly controlled by the State Department, but nowhere in the draft EIS or in other State Department documents do we find an explanation for our government's acquiescence in a regime-drafting schedule which makes full compliance with the CEQ Guidelines on the temporal relation of an EIS to agency decision-making impossible. It is essential to the effectiveness of the process required by NEPA that the State Department see to it that multilateral negotiations involving the United States take place in a time-frame which, whenever possible, allows the Department the time required to go through the EIS comment process before making and acting on the decisions which the comment process is supposed to affect.

(2) The distribution of the draft EIS was entirely inadequate. At the very least the draft EIS should have been sent to all the scientists who are participating in the BIOMASS study and to other
36 active members of the SCAR/SCOR Group. It was our experience, however, that these and other polar experts did not receive copies of the draft unless they or a concerned third party requested one to be sent to them. This is inexcusable. The number of persons expert in Antarctic matters is not so great nor are their names and addresses so inaccessible that the State Department could not have quite easily sent the draft to each of them. We trust that in distributing the final EIS this deficiency will be remedied.

These then are the substantive and procedural shortcomings which we have found in the draft EIS. We know that you share our desire to see the current negotiating process produce an effective marine living resources regime for Antarctica, and we are more than willing to help you and Ambassador Brewster achieve that objective. We hope that these comments on the draft EIS have been helpful to that end and we hope that we can be of more assistance in the future. We would welcome the opportunity to discuss our criticism of the draft EIS with you and to go into more detail on the positions we have taken in this letter.

Sincerely,

James N. Barnes

James N. Barnes

John Robinson

John Robinson
Center for Law and Social Policy
1751 'N' Street, N.W.
Washington, D.C. 20036
(202)-872-0670

These comments on the draft Environmental Impact Statement for a Possible Regime for Conservation of Antarctic Living Marine Resources are jointly submitted on behalf of the following organizations:

Environmental Defense Fund
1525 18th Street, N.W.
Washington, D.C. 20036

Friends of the Earth
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Washington, D.C. 20003

Natural Resources Defense Council
917 15th Street, N.W.
Washington, D.C. 20005

Sierra Club
330 Pennsylvania Avenue, S.E.
Washington, D.C. 20003

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*Committee for Humane Legislation, Inc.* 2101 L Street, N W , Washington, D C 20037 (202) 452-1430

*Regina Bauer Frankenberg*
*President*
*Alice Herrington*
*Executive Director*
*Bernard Fensterwald, Jr*
*Counsel*
*Jowanda Shelton*
*Washington Director*

April 14, 1978

Mr. William H. Mansfield III
Office of Environmental Affairs
Department of State
Room 7820
Washington, D. C. 20520

Dear Mr. Mansfield:

This letter is in response to the public announcement of a comment period on the Draft Environmental Impact Statement for a Possible Regime for Conservation of Antarctic Living Marine Resources (Department of State Public Notice 60).

The Committee for Humane Legislation wishes to submit the attached statement as our comments on the Draft Environmental Impact Statement and respectfully request that these comments be given serious consideration in the Department of State's negotiation of a proposed Possible Regime for Conservation of Antarctic Living Marine Resources.

Yours very truly,

Jowanda Shelton

Jowanda Shelton

JS/mld
Enclosure

## COMMENTS OF THE

## COMMITTEE FOR HUMANE LEGISLATION, INC.

April 14, 1978

### A(1). No Action

No action is not acceptable. The International Whaling Convention and the Convention for the Conservation of Antarctic Seals as examples have proven to be nothing more than the meeting together of those countries who have an interest in taking and using the marine animals. Although there are no plans to "fish" in Antarctic waters there is no assurance that some nations will not expand their fishing as soon as the over-fishing of stocks in warmer water pushes the fishermen into new waters. Regulations are not needed but protective action is needed immediately. Protection of the whales and the seals should also be included in any proposed federal action taken with a view toward total protection rather than harvesting as has resulted from the IWC and CCAS.

### B(2). National Action

Individual national action would be the same as no action at all. Each nation would be proceeding independently and would eventually compete with other nations for the individual species of the ecosystem. Competition for "taking" would soon decimate all living creatures.

### C(3). Negotiation of an International Agreement for Collection, Exchange and Analysis of Data

Negotiation of an International Agreement for Collection, Exchange and Analysis of Data would provide no protection of the marine species. Such agreement, without full disclosures as to reason for the collection, exchange and analysis of data, should not be accepted. If scientific data collection kills the marine life in order to learn more about that life, the methods then do not justify the end. Such International Agreement must explain clearly the purpose for which data is collected and must provide assurances that the ecosystem will not be disturbed or animals harassed in the process of deciding how to conserve. Apparently the entire alternative suggestion presupposes harvesting as the end object. If the scientific data is gathered only as harvest data, it is unneeded.

### D(4). Negotiation of an International Agreement Establishing a Complete Conservation Regime

Negotiation of an International Agreement to establish a complete conservation regime includes a statement, "In addition, under this approach, harvesting could take place in the interim period after the entry into force of the regime and prior to the development of conservation measures pursuant to the regime." The object again, presupposes the final conservation effort made in the Antarctic would include "harvesting." Harvesting before and during "conservation" planning would surely include species which may be completely wiped out during the long planning period. The final plan would therefore be obsolete before it is begun. The unknowns of the ecosystem demand total preservation.

D(4). (continued)

### E(5). Negotiation of an International Agreement Establishing Specific Conservation Measures or a Temporary Moratorium

Option E presents a temporary moratorium, the only sane interim alternative. A total moratorium on the taking (harvesting) of all Antarctic marine living resources without exception or "interim catch limitations" would assure the preservation of all living plant and animal life whether it exists in abundance or limited supply.

The alternative International Agreement should, of course, agree completely with federal action as an example of good faith intentions as well as national public support as represented in the U. S. Congress.

The agreement should be as detailed as possible to leave no species unprotected. The final agreement goal should be permanent moratorium. A major drawback listed is conversely no drawback as the collection of data would be for the purpose of eventual harvesting. Incentives would be strengthened as encouragement to other nations to ban the taking of living organisms from the natural ecosystem of the Antarctic. In fact, to take while determining "conservation measures" would not present a fair or factual report on the natural area. An effective "conservation regime" should include as many nations as possible - harvester and non-harvester alike.

### F(6). A Total Ban on Harvesting

The Committee for Humane Legislation supports alternative F. The total ban on harvesting presents the only alternative both as an interim proposal and final agreement. To take a strong U. S. position in an interim agreement would encourage other nations to join with our nation in the preservation of the Antarctic ecosystem.

The "assumption that properly controlled harvesting of Antarctic marine living resources is consistent with maintenance of the health of the Antarctic marine ecosystem" is a totally false one based upon "properly controlled harvesting" of animal species in the United States.

F(6). (continued)

Hundreds of species of animals are listed on the endangered species list nationally and hundreds more are listed as endangered within the states. Unknown numbers of plant species have been uprooted in the effort to farm favored vegetation for select species of animals.

Pages 22 and 23 of the DEIS discuss the Food Web existing in the Antarctic. I quote the second paragraph as strong evidence for banning the harvesting of krill:

> "The dependence of many predators on one prey group, krill, is a very unusual ecological situation. The predators divide up the available krill resource by feeding in different geographic regions, at different times of year, and on different size classes of krill. Removal of krill from the ecosystem by commercial harvesting will compete directly with those species feeding on the same part of the krill stock which is harvested, and indirectly with other predators as overall krill abundance changes."

"No regulation whatsoever" should not be construed to mean no protection.

Preservation of the Antarctic marine ecosystem as a sanctuary is an obtainable goal and indeed should be the only goal. The most serious effort should be made by the United States' Department of State to attain this goal before declaring it an "unobtainable objective." Further proof should be offered by the Department of State in support of their allegation that "a total ban on harvesting stands almost no chance of being negotiated."

## G. Area Covered by the Regime

The difficulty stated in alternative G, "The difficulty with this approach (to fix a geographic limit for the applicability of the regime) is that it would cover species not part of the Antarctic marine ecosystem and thus create difficult and political obstacles to negotiating the regime," is a necessity whether or not the problem is difficult.

Geographic limits should be as broad as possible in order that as many animal and plant species as possible may be preserved under the International Agreement.

Although pollution is discussed throughout the DEIS, the passage of the oil freighters between the Antarctic Continent and other continents is of serious concern and should be considered in any "conservation" regime of the Antarctic. Oil spillage is a serious threat to the wildlife in the area.

G. (continued)

Overharvesting plus one accidental oil spillage could destroy a whole area - possible krill breeding areas - in turn destroying food essential to animal survival.

It is important that all areas where oil tankers pass be included as a part of the "conservation regime."

* * *

IIED INTERNATIONAL INSTITUTE FOR ENVIRONMENT AND DEVELOPMENT
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7th April 1978

Mr. William H. Mansfield
Office of Environmental Affairs
Department of State
Room 7820
Washington D.C 20520

Dear Mr. Mansfield,

IIED submitted comments on the Draft Environmental Impact Statement on a Possible Regime for Conservation of Antarctic Living Marine Resources on 10 February 1978. We would now like to make some additional points which should be regarded as complementary to the first set.

We enclose, in addition to our original comments, an analysis by Dr. John Beddington of the Department of Biology, University of York, U.K.* We are now working with Dr. Beddington, on a project sponsored by the World Wildlife Fund and the International Union for the Conservation of Nature and Natural Resources to investigate the problems of management with respect to the objective of protecting the Antarctic marine ecosystem and of accommodating the interests of the international community. (Dr Beddington will be constructing a mathematical model of the dynamic relations that might be thought to hold between krill stocks and predators on them)

Both Dr. Beddington's comments and our own are necessarily limited at this time because we are just embarking on the project. As this work progresses we would be happy to forward you any written work generated.

Yours sincerely,

Richard Sandbrook
Barbara Mitchell

Enc.

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* We understand that a copy of this has also been sent to you under separate cover.

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IIED INTERNATIONAL INSTITUTE FOR ENVIRONMENT AND DEVELOPMENT
*President:* Barbara Ward (Baroness Jackson of Lodsworth, D B E )

# Comments on the Draft Environmental Impact Statement for a Possible Regime for Conservation of Antarctic Living Marine Resources

(Department of State, February 1978)

Submitted on behalf of the IIED*

by Barbara Mitchell, Research Associate, February 10, 1978

## Introduction

In the Draft Environmental Impact Statement for a Possible Regime for Conservation of Antarctic Living Marine Resources, the Department of State indicates the intention of the Government to seek an international agreement which would "set forth the objectives of the regime and provide the obligations, functions and machinery necessary to fulfill them." As they are described in the statement, the objectives of the regime are sound. We are concerned, however, that the means by which the Government hopes to meet them are left too vague.

There is, in effect, a danger that the proposed Government action will result in a regime more like the rejected "no-action-now" aonroach than the US Government actually intends. In criticizing the latter approach on page 4, the draft EIS describes the drawbacks of a gradualist attitude. It refers to " extensive evidence" from efforts to conserve marine resources in other areas of the world, that'"after the fact" regulation is not effective.' It notes that "Initiation of effective regulation would likely be more difficult once substantial economic stakes in uncontrolled methods of harvesting are created".

We have no objection to a degree of flexibility in approaching this task, as long as it is backed up by the strongest textual guarantees. Some of these will be difficult to negotiate but it should be borne in mind that decisions made here will be of the greatest and most lasting importance for the future of what may become the world's major fishery. The following elements of the regime require further consideration:

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* IIED is a non-profit research organization with offices in Washington and London. It is considered a tax-exempt organization under the US internal revenue code.

### 1. Interim arrangements

The immediate introduction of some form of regulation of the fishery is essential. In the description of proposed federal action on page 6, the draft EIS suggests two ways of dealing with the treatment of harvesting in the interim period after the entry into force of the regime and prior to the development of conservation measures. The first would be to assume that "technological and other limitations will ensure low harvesting levels for the next several years." The statement recognizes, however, that if the development of conservation machinery takes longer than is presently anticipated, this variant would involve some risk of overexploitation. The second sub-option would be to negotiate, as a supplement to the international agreement, very conservative catch limitations, at least for krill, with provisions for phased expansion of that limit by fixed annual percentage increases over a fixed and limited period of years.

We fully endorse the statement on page 7 favoring the latter option. Although this would be more difficult to negotiate, it indeed reflects a more sensible approach to the exploitation of a resource with which

there is little international experience. We trust that this sub-option will be adopted and hope that it will be fully negotiated before the convention is signed.

### 2. Development of conservation measures

The tools of conservation should be spelled out in the convention. The proposed federal action would leave the development of specific conservation measures to the decision-making body established under the agreement. The draft EIS contrasts this with another approach to the establishment of a full conservation regime (alternative 5) which would involve negotiation in the international agreement of specific conservation measures for some or all Antarctic marine living resources.

The statement recognizes that the latter alternative would pose fewer risks to the Antarctic marine ecosystem than the preferred governmental action. However, it suggests that there is insufficient data upon which to base specific conservation measures and that an attempt to introduce such measures *ab initio* could significantly decrease incentives for nations with harvesting interests to participate in the conservation regime.

We are aware of the need to make the regime palatable to harvesting nations but feel that the earlier the tools of regulation are introduced, the easier it will be to apply them. While we do not claim that sufficient information is already available to establish catch limits and other specific conservation measures on a long-term, definitive basis, we do feel that the appropriate decision making body (the Commission in the Government proposal) should be explicitly empowered in the convention to implement controls in the following areas:

- Catch limits for each species, according to
  - age or size class
  - geographic area
  - season
- Total catch limits for each species
- Allowable gear
- Total effort or time spent in harvesting
- National catch and effort allocations
- Annual increases in national effort and catch

At the recent London meeting of the Antarctic Treaty Powers the 38 possibility of catch allocation was excluded for political reasons relating to the unsolved Antarctic territoral claims issue. This omission will seriously handicap any attempts at conservation. The U.S. delegation to Canberra should reintroduce the principle of national catch and effort allocation now and ensure that any institutional mechanism established be empowered to raise the issue at a future date.

## 3. Decision-making

### a) Scientific advice

As it is described in the draft environmental impact statement, the proposed Government action will not ensure that economic and 39 other considerations are prevented from overriding scientific advice in decision making. Furthermore, we are not given sufficient guarantees as to the impartiality of the scientific advice which will be provided.

The statement simply calls for the gathering of full information on the marine ecosystem and the effects of harvesting, and the injection of this material into the decision-making process. Thus, standing bodies are to be established *inter alia* to acquire scientific data on the nature of the Antarctic marine ecosystem, and identify stocks to which conservation measures should be applied. They are to "prepare for the periodic meetings of the plenary body or commission" and "monitor the effectiveness of conservation measures." The plenary body itself, made up of representatives of contracting parties to the regime would "decide upon conservation measures". More details are needed on the relationship between the commission and any standing scientific body. Furthermore, who will be responsible for the scientific work and how will they be funded?

### b) The Commission

Clarification is required on decision making in the Commission. This should be open, and all information on which decisions are based, made available to the public. (The present practice followed by the Antarctic Treaty powers of holding meetings behind closed doors and of restricting circulation of documents often leads to mistrust of their claim to be acting on behalf of all mankind.) In addition, there should be no veto rights and the Commission's rules should be binding.

### IV. Finance

Details are needed on the projected financial arrangements. We note on page 58 that the US would support the scientific research necessary to establish conservation policies and that it would expect to contribute a share of the cost of running the regulatory organization set up. It is vital that the convention seek a similar commitment from each contracting party. In particular, there must be a guarantee that all research work, including the monitoring of non-target species which might be affected by harvesting but are not of (immediate) economic interest, be adequately financed on a long-term basis.

### V. Enforcement

40 The draft EIS makes no detailed reference to the all important question of enforcement. Provision should be made for effective enforcement and policing of any arrangements. The appointment of independent observers and their right to carry out inspections of all fishing operations should be written into the convention. Flexible settlement of dispute provisions should also be included.

### VI. Links with the International Whaling Commission and the Convention for the Conservation of Antarctic Seals.

41 Provision should be made in the convention for full co-ordination between the activities of the conservation agreement and both the Convention for the Conservation of Antarctic Seals and the activities of the International Whaling Commission, if the regime is to meet its objective of providing for the "effective conservation of the marine living resources of the Antarctic ecosystem as a whole". The draft EIS leaves this task to a standing body to be created under the convention.

### VII. International Community

Steps should be taken to protect the interests of the broader international community in these marine living resources.

42 Protein-rich krill may have an important role to play in helping the vast numbers of undernourished individuals in developing countries. The technology required to harvest and process the resource is such, however, that for some time to come this field will remain the almost exclusive preserve of the developed world unless deliberate action is taken to allow other countries to benefit. We regret to note that the proposed federal action does not address this point. On present indications the regime will provide for no more than freedom of access for those able to develop the resource.

There is a precedent for taking into consideration the interests of the international community in krill. In the preamble to the Antarctic Treaty, the Consultative Paries recognize that "it is the interest of all mankind that Antarctica shall continue forever to be used exclusively for peaceful purposes and shall not become the scene or object of international discord." Furthermore, in the

London meeting, the Thirteen Antarctic Treaty Consultative Parties recommended to their governments that "the Consultative Parties, in dealing with the question of mineral resources in Antarctica, should not prejudice the interests of all mankind in Antarctica".

We recognize that what is being established is a conservation regime. The draft EIS notes, however, on P. 54 that US interests in the conservation of Antarcticmarine living resources include the rational development of new sources of protein and the prevention of international conflict over Antarctica as well as a commitment to maintaining the Antartic environment. National expectations and investments in krill are growing daily. Postponement of this issue may make it politically impossible to negotiate any proposal to ensure that this source of protein is used to maximum benefit. Facing the issue now would mean that at a later date, if and when it is found that sufficient quantities of krill can be safely recovered every year, parties to the convention would be able to take the appropriate action to enable developing countries to benefit from the resource. These concerns should be reflected in three different ways:

a) The convention should include a general provision recognizing the interests of the international community in the living resources of the area, along the lines of the recommendation on mineral resources quoted earlier.

b) A strong institutional relationship between FAO and the living resource regime should be written into the convention. In the past this organization has shown interest in a joint program with the UN Development Program to assist in the exploration, exploitation and utilization of krill for the world as a whole. Although the proposed federal action anticipates a "close working relationship" with FAO (P.12), it again leaves the establishment of this link to a standing body to be created pursuant to the regime.

c) Delegates from international organizations such as FAO as well as all krill fishing nations should participate in the next meeting held to discuss the regime after Canberra. We understand that it is a US goal to invite other parties. But, to make this participation meaningful, options should not be foreclosed in Canberra and Treaty parties should not present "outsiders" at the next meeting with a fait accompli. Furthermore, "outsiders" should have a full voice at this next meeting.

In short, we feel that a good many elements of the regime should be spelled out in greater detail in the description of proposed federal action, in the U.S. position papers prepared for Canberra, in the Final Environmental Impact Statement, and, most importantly, in the convention itself. We believe this to be the best way to ensure that this important regime is both sound and equitable.

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# Supplementary comments on the Draft Environmental Impact Statement for a Possible Regime for Conservation of Antarctic Living Marine Resources.

By

Richard Sandbrook and Barbara Mitchell

I.I.E.D.
London

6 April 1978.

In our comments of February 10, 1978, (Appendix I), we criticised the proposed federal action on the grounds that it was too vague as to the means by which the Government intended to meet the objectives of sound management that it had identified. There are two aspects to this vagueness. First, the description itself is too imprecise. Second, many important elements of the regime, such as the underlying principles and the mechanisms for conservation are, it seems, to be left to the Commission to decide upon. We appreciated that detailed conservation measures could not be drawn up ab initio because of the lack of necessary data, but still felt that more needed to be negotiated before the convention was signed. We would like to see a detailed management structure and its scientific criteria for operation , made explicit.

Having considered the approach of Dr Beddington to the biology of the Southern Oceans (see Appendix 2) which brings out the dynamic nature of the ecosystem, we would simply reiterate our concern that a strong regime be established from the outset. It is clear that the possibility of changing the system irreversibly by overfishing the zooplankton trophic level is real and therefore a cautious step by step approach to increasing the annual yield is called for. Given the delays involved in the ratification of international conventions and the time it might then take for a scientific committee to establish suitable catch limits, we feel it is essential that such limits be set (in the convention), to come into operation immediately. We would also like to underline again the need for national allocation of both catch and effort, without which the conservation regime will be meaningless. While we appreciate the political difficulties involved in mentioning this in the convention (given the jurisdictional disputes), and the clear preference of a number of nations to leave this to later, informal bargaining, we would point out that, in the absence of agreed criteria, which it would surely be easier to hammer out now than later, the wrangling over allocation in any separate meetings of fishing nations will be long drawn out and, quite possibly, inconclusive.

*North American Office : 1302 Eighteenth Street, N.W., Washington D.C. 20036*
*Telephone (202) 462-0900*

There are further points which we should like to raise:

1. The likely rate of build up of the krill fishery.

43 Apart from the statement (p. 36) that "Probably within 10 years, and almost certainly within 20 years, a capability for over-exploiting krill will exist", the draft environmental impact statement does not attempt to draw a picture of the future development of the fishery and the pressures this will place on the regime. A detailed prediction may be difficult at this stage but without a first impression of the rate at which the fishery will develop it is difficult to say which controls should be introduced and when. It is certainly impossible in the absence of further information to be confident that the arrangements described in the proposed federal action will be sufficient. It is our feeling that they will not.

2. The secondary impacts of the krill fishery.

a) Redeployment of fleets

If we assume that a large fishery could build up in the Southern Ocean and that the fleet would only be able to operate in the short Antarctic summer (4-5 months) then the effects of such a fleet operating elsewhere during the remainder of the year could be important. For example, we estimate that a fishery of, say, 20 million tons could require between 3 - 5,000 ships, with support ships (of an average of 4000 H.P. and 90 L.O.A.) working for the 150 day season with a catch of 4000-6000 tons per season per ship (after Eddie, FAO 1977). If one considers, in comparison, that the entire UK distant water fleet is estimated at 340 ships, then the effect that these vessels could have on other fisheries is substantial.

It is our view that such second order effects are highly significant given the current state of world fishing. It is possible and to an extent probable that the initial tonnage required to maintain the krill fishery will be deployed out of existing fleets and, in the short term, this could have a beneficial effect on catch/effort ratios elsewhere. But it is equally possible that a rapid build up of new Antarctic fleet could follow given the favourable climate for expanding the Southern Ocean fishery (high initial catch rates with available fleets, emergence of new product markets, anxiety on the part of certain countries to protect future rights to the resource by engaging in high levels of activities now).

b). Effects on the markets for products such as fishmeal or other forms of protein for human consumption.

The increasing supply of protein from the Southern Ocean will have a number of secondary impacts on markets for traditional sources of protein eg soya, prawns and anchoveta. We wonder if these are thought to be significant by your experts.

3. The need for an internationally respected Treaty.

Whatever one's views on international equity, there are other compelling reasons why the interests of the international community should be accommodated in the future regime for Antarctic marine living resources. Given the continuing world food crisis, a number of developing countries may ultimately be tempted to turn to krill exploitation. If they are to abide by the conservation rules set for exploitation in the area, they must feel that the arrangements have something to offer them. This argues for involving the FAO and other appropriate international agencies in the negotiations before options are narrowed. It also calls for a wide measure of accommodation of international community interests in the final regime. One element of this would be the inclusion of independent fishery scientists currently outside the negotiations of the Treaty Parties, to advise on exploitation criteria, both in the negotiating process and in the final arrangements. With respect to the latter, there should be a provision allowing the chairman of the future scientific body, established under the Antarctic marine living resources convention to invite such experts to participate in the work of this organ.

MONITOR
*THE CONSERVATION, ENVIRONMENTAL
AND ANIMAL WELFARE CONSORTIUM*

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DEPARTMENT OF STATE

Hon. Robert Brewster
Deputy Assistant Secretary for Oceans
and International Environmental and
Scientific Affairs
U. S. Department of State
2201 C Street
Washington, D. C. 20520

February 22, 1978

Dear Ambassador Brewster:

The following Monitor groups endorse this letter:

Society for Animal Protective Legislation
Animal Welfare Institute
Humane Society of the United States
International Fund for Animal Welfare
Rare Animal Relief Effort
Washington Humane Society
International Primate Protection League
Fund for Animals
Defenders of Wildlife
Sierra Club
Let Live

44 We are deeply concerned that option E, among the alternatives to the proposed federal action on negotiation of a regime for conservation of antarctic marine living resources, has not been selected.

The establishment of an interim moratorium while scientific studies are conducted would follow the system adopted by the Congress under the terms of the Marine Mammal Protection Act of 1972. This is a sound, conservative approach, differing from the proposed federal action in that it provides time to ensure that serious errors are not made.

We understand that the Department of State does not believe it is a feasible alternative from the point of view of achieving agreement by other nations. However, until an effort is made to obtain this clearly more desirable objective, it is not possible to foresee whether or not other countries would support a U. S. move for an interim moratorium.

The massive lack of biological data is recognized in the DEIS. U. S. leadership and negotiating skill might well succeed in persuading those concerned to accept a five-year moratorium. We strongly recommend that the U. S. delegation take this position and work for it. If it proves impossible to persuade the other nations to agree, the currently proposed federal action could take the place of the fall-back position.

Further, we urge that the delegation reject the position adopted at the ninth consultative meeting and seek individual catch limitations. Total catch limitations are not adequate to ensure protection of this fragile ecosystem.

The regime should incorporate an observer program to ensure that whatever decisions are adopted are adhered to. The importance of observers has been irrefutably established in the enforcement of the Marine Mammal Protection Act with respect to incidental catch of dolphins in tuna purse seines. The International Whaling Commission requires international observers on factory ships.

We are concerned that there has been a lack of public involvement in matters relating to exploitation of living marine resources of the antarctic. We believe the public generally would favor the moratorium approach were they adequately informed of the dangers of overexploitation in the antarctic.

The campaign to save the whales in the United States has major public support and interest. Public concern with seals is enormous. But the public knows little or nothing of the plans of our government which will affect the fate of marine mammals. We note on page 58 of the DEIS that "the United States expects to support the required scientific research which will aid in the establishment of conservation policies. The United States will continue to fund scientific research in the Antarctic." Thus the public is involved through the payment of taxes.

On page 41, we note that a ban on harvesting "is the most favorable alternative for recovery of whale stocks." A moratorium, although only a temporary ban, would provide assistance at this time when stocks of whales are at their lowest ebb.

We also urge that any Antarctic agreement should require that signatory nations that conduct commercial whaling must be members of the International Whaling Commission.

We urge you to seek a moratorium.

Sincerely,

Craig Van Note

Craig Van Note
Executive Vice President

National Audubon Society
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RECEIVED
OES

March 16, 1978

Mr. William Mansfield, III
Office of Environmental Affairs
(Room 7820)
Department of State
Washington, D.C. 20520

Re: Draft Environmental Impact Statement
for a possible Regime for Conservation
of Antarctic Living Marine Resources

Dear Mr. Mansfield:

1. At the outset, it should be noted that the Draft Environmental Impact Statement suffers from an inherent ambivalence: Was it intended to guide the Canberra negotiations now taking place, or rather as a discussion of the regime, the outlines of which will emerge from Canberra? That is unclear. Unfortunately, it satisfies neither purpose.

As a policy paper for the Canberra meeting, the DEIS was issued too late, February 1, to give adequate opportunity for full comments at the public meeting held by the Department February 10. Indeed, National Audubon's copy arrived only February 13; we were fortunate, in advance of the meeting, to have received a photocopy of the text (less appendices) from another organization.

Prepared as it was in advance of the negotiations which are only now giving shape to the regime, the DEIS is obviously inadequate as a discussion of the all-important details which alone will determine the effectiveness of that regime. For this purpose, it is largely academic, a general outline of Antarctic living marine resource issues and theoretical options, hardly a paper on which long-term policy decisions can or should be based.

45 We would be interested to know what practical use the Department plans to make of these comments.

2. We believe the matter of the timing of the DEIS deserves further comment. We are at a loss to understand why the Department has been unable to plan its preparatory process in such a way to allow the orderly develop-
46 ment of U.S. policy on this issue, including adequate input from the nongovernmental community.

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The Commerce Department, on the other hand, regularly begins its preparation of the U.S. position for the International Whaling Commission five months before the annual IWC meetings take place; that preparation involves a number of substantive meetings in which nongovernmental representatives are invited to participate. In our view, a December 20 public meeting, which involved only general discussion, and a February 10 public meeting, to discuss a DEIS issued only 10 days previously, are hardly sufficient to allow public input for negotiations beginning February 27. The future of Antarctic living marine issues deserves better.

3. We believe the list of seven alternatives is inadequate. There is no evidence in the DEIS that those identified are the only reasonable ones available. They appear rather to be arbitrary points on a broad spectrum of possibilities.

4. In view of its emphasis on exploitation, one would conclude from the DEIS that the proposed living resources regime is first and foremost a fisheries regime. Nowhere is it stated with adequate clarity that the primary object of the regime is conservation of the living marine resources of Antarctica. Nowhere, equally, are critical scientific and aesthetic aspects of the regime addressed. These are failings that must be redressed.

5. The DEIS is replete with statements concerning the lack of knowledge of the population numbers for various species. Yet the validity of the proposed Federal action, alternative D, must rest on a tacit assumption that enough is known to justify exploitation.

47 6. The second sub-option of alternative D proposes the establishment of catch limitations for an interim period after entry into force of the regime. We believe such limitations should not be delayed for years; they should be agreed upon immediately and put into effect, on an interim basis, not later than the conclusion of a draft convention.

We further believe that catch limitations are unenforceable without national catch allocations. The U.S. should reject the position adopted in this regard at the Ninth Consultative Meeting. Both catch limitations and allocations should be monitored by an effective observer program.

48 7. We would appreciate clarification of the NEPA procedure the Department intends to pursue. We trust that it will be issuing a supplemental draft statement upon the return of the delegation from Canberra.

8. For the future, we urge the prompt establishment at last of an open and substantive advisory process which gives the public more than pro forma involvement in the development of Antarctic policy.

Timing is an important element of such a process. Equally, as not all materials relating to Antarctica require confidential treatment, there should be freer access to position papers as they are developed by the various agencies. To refer once again to the IWC preparation process, we believe the joint meeting at NOAA of agency and nongovernmental representatives a valuable precedent.

Sincerely,

Chaplin B. Barnes

Chaplin 8. Barnes
Director of International Activities

CBB:tv

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NEW YORK ZOOLOGICAL SOCIETY

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New York Aquarium
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1978 APR 21 PM 6

17 April 1978

DEPARTMENT OF STAT

Ambassador Robert Brewster
Bureau of Oceans and International
Environmental and Scientific Affairs
U.S. Department of State
Washington, D.C. 20520

Dear Ambassador Brewster:

The staff of the New York Zoological Society is fully supportive of the efforts being made by the Antartic Treaty powers to conclude an agreement on the conservation of living resources of the Southern Ocean. We are particularly appreciative of the role the U.S. delegation has played in these efforts. However, we are deeply concerned that the Draft Environmental Impact Statement for a Possible Regime for Conservation of Antarctic Living Marine Resources, February 1978, is inadequate in its treatment of the Southern Ocean ecosystem. This ecosystem, like that of most complex natural communities, can respond to outside disturbances in a variety of ways. The DEIS treatment to the contrary suggests a rather simplistic unidirectional response. This deficiency is discussed briefly in the attached critique of the DEIS by Dr. J.R. Beddington of the University of York, who is developing a computer model of the Southern Ocean's Ecosystem in collaboration with the International Union for the Conservation of Nature and Natural Resources's (IUCN) Marine Programme and the World Wildlife Fund's Seas Must Live Campaign.

The Zoological Society staff is also concerned that the DEIS largely treats the Antarctic marine ecosystem as though it were divorced from the rest of the oceans. In fact, man's manipulation of the Southern Ocean resources may well have severe impacts on distant marine ecosystems. For example, as surface waters are cooled in the Antarctic they sink and flow north toward the Equator. These nutrient-rich waters well up in several places where they support a large fisheries industry. Major disturbances of the Antarctic living resources may well affect these remote resources in places like Peru. The DEIS must address this possibility.

As Dr. Beddington's research progresses, we will have a better understanding of the Southern Ocean's responses to krill harvesting and possibly other factors as well. Additional information on Dr. Beddington's research can be obtained either directly from him or from the IUCN. It is our hope that Dr. Beddington's expertise and that of the IUCN will be used to correct the deficiencies of the DEIS and also in the development of the U.S. position for future negotiations on a regime for conservation of the Antarctic living marine resources.

Sincerely,

F. Wayne King
Director of Zoology
and Conservation

/db
Enc.
cc: P. Mink
L. Talbot
American Comm. for Int. Conservation/Exec. Board
M. Segnestam/IUCN
J.R. Beddington

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POINT REYES BIRD OBSERVATORY
Mesa Road, Bolinas, California 94924

18 April 1978

Mr. William H. Mansfield III
Office of Environmental Affairs
Department of State
Room 7820
Washington, D. C. 20520

Dear Mr. Mansfield:

By the time the original deadline had passed for comment on the draft EIS for a Possible Regime for Conservation of Antarctic Living Marine Resources, I had not seen a single copy. Since then three copies have arrived from various sources, including your office! Thank you. I am glad to hear that the deadline has been extended but am disappointed that our representatives at the Canberra meetings were without the benefit of knowledgeable public discussion on the position they would be trying to negotiate.

49 I heartily support the views of the Marine Mammal Commission on the DEIS as expressed in Mr. Twiss's letter of 20 March. It constitutes a very knowledgeable review. I request that you consider each point carefully when revising the DEIS because in doing so I think the document can be strengthened considerably. There are a few points that I would like to emphasize. The first is that we are negotiating a conservation convention and not a fisheries convention. In the latter, major energies would be devoted to division of the resource so that all interested parties receive their share without damage to the resource. In the former, we are interested mainly in protecting the resource and at the same time allowing for regulated exploitation. This then brings me to the next point. At present, because of insufficient knowledge, the only way we can define over-exploitation of Antarctic resources is through trial and error. While this is often the regime of fishery conventions, it may be especially inappropriate for the Antarctic in that major fisheries have never before dealt with such a simple ecosystem and have never before proposed harvest of the animal (krill) most central and basic to an entire ecosystem. Furthermore, there is no state or organization present to monitor fishing activities, enforce conventions, and to slow exploitation when the trial fails. This is further aggravated by the fact that we are dealing with a pelagic fishery. Historically, such fisheries have had the poorest conservation-of-resource records because regulation is so difficult.

Because of these problems, our position early in the game should be a strong one. Later, when tremendous amounts of capital have been invested and many persons' livelihoods depend on the fishery, the task of conservation will become much more complex and difficult and not any less important. As examples, witness the success of efforts to prevent whales from being over-exploited, or the difficulty in preventing damage to porpoise populations by the tuna industry. In these examples, the issue evolved from being one merely concerned with conservation of an animal to an issue of animals vs people's jobs. I therefore support the proposed federal action but feel that some conservation measures must also be negotiated for at the outset to the end that time will be made available to assess resource stocks and establish limits before fisheries are established.

One final point is that present estimates of how much krill can be harvested are based on estimates of what Antarctic whales used to consume (the whales have now mostly disappeared). It seems to me that because of the U.S. position on whaling, we are more or less committed to a krill harvest that would be small enough that whale populations would be able to recover. Notwithstanding the fact that the present estimates (maximum ones anyway) are based on little direct data and unsound biological reasoning (an example: whereas whales eventually returned much of what they took from the Antarctic ecosystems---thereby maintaining energy cycles---humans would remove the krill resource without compensation to the system; this becomes important because krill are so basic to the system in the first place), I can not see how we can support krill harvest quotas anywhere near the highest estimates. And when it comes to actually establishing "sustainable yields", these have to be defined in terms of the system and not just the exploited stock.

Sincerely yours,

David G. Ainley

David G. Ainley, PhD

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# COMMENTS ON THE
# DRAFT ENVIRONMENTAL IMPACT STATEMENT
# BY
# PRIVATE INDIVIDUALS

UNIVERSITY OF YORK
YORK, YO1 5DD, ENGLAND
TELEPHONE 0904 59861

DEPARTMENT OF BIOLOGY
Dr. J. R. Beddington

29th March, 1978

William Mansfield, Esq.,
Office of Environmental Arrairs,
United States Department of State,
WASHINGTON DC,
U.S.A.

Dear Mr. Mansfield,

I enclose a copy of some preliminary comments on the draft environmental impact statement for a possible regime for conservation of Antarctic living marine resources.

Yours sincerely,

J. R. Beddington.

Enc.

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Comments on the draft environmental impact statement for a possible regime for conservation of Antarctic living marine resources.**

J. R. Beddington and J. H. Lawton.*

General Comments

The central problem of the environmental impact statement and particularly its Appendix C is that it concentrates exclusively upon a static picture of the ecosystem and pays no more than lip service to dynamic considerations or indeed to current ecological theory. The crucial problems that need to be faced concern the possible equilibrium states of the Southern Ocean Ecosystem and the dynamic trajectories that are likely to occur as these are approached. The linear compartmental modelling approach implicit in the draft statement and used in Green (1975, 1977) is incapable of producing much insight into these problems. Such analysis can be useful in analysing behaviour close to an equilibrium state, but is a poor tool for predicting the existence and stability of other possible states of the ecosystem. It is thus an inappropriate method for study of the current state of an ecosystem which has suffered the massive perturbation produced by the depletion of the baleen whales, or for assessing the likely response of the system to the perturbation caused by extensive krill harvesting. Recognition that the system is non linear and hence capable of having a multiplicity of stable states is essential both for assessing the implications of various management strategies and for specifying research needs. (Beddington, Free and Lawton 1976; Conway 1977; Holling 1973; May 1977; Noy-Meir 1975.)

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* Department of Biology, University of York, YORK YO1 5DD, U.K.

** These preliminary comments arise from a project funded by I.U.C.N. and the World Wildlife Fund aimed at analysing and modelling the Southern Ocean Ecosystem's response to krill harvesting.

## Specific Points

It is not appropriate in this document to comment in detail upon all the problems in the statement, instead we select two. The first concerns the level of krill harvest that will not permit recovery of the baleen whale populations, the second with the immediate response of the system to krill harvesting. It is well known that homiotherms invest a very high proportion of energy intake in basal metabolism (McNeill and Lawton 1970; Golley and Buchner 1968) and if their food intake falls they do so at the expense of growth and reproduction (Brody 1945). Hence quite small changes in

51 feeding rate can make a considerable difference to reproductive performance. This has been documented for baleen whales in the Southern Ocean where growth rates and fecundity have increased following exploitation (Gambell1976), and for the sei whale Balaenoptera borealis it has proved possible to relate these changes both to changes in sei whale density and to changes in densities of competitor species (Beddington 1978). A corollary of this, is that at certain levels of krill depletion the demographic parameters of the baleen whales will be such that the populations will decrease whether harvested or not. Nowhere in the draft statement is this problem addressed or apparently recognised. The only relevant piece is page C-7 paragraph (1) where it is noted that a krill harvest might lead to a "slower recovery of the baleen whale population" and would limit "the potential baleen whale population size." This problem is exacerbated by two factors, there is a complex migration pattern of the baleen whales into the Antarctic waters during the summer (McIntosh 1965) and it seems clear that this pattern is finely tuned to the life cycle of the krill. There is thus a problem that inappropriate timing of the commercial krill harvest could affect the feeding efficiency of the whales out of all proportion to the total level of that harvest. Similarly commercial harvesting is likely to operate in geographical locations where krill concentrations are highest and it is just these concentrations which are used by the baleen whales. Hence local depletion of the krill could seriously affect the energy balance of the whales which have to swim further for less abundant food. It is pertinent to note in concluding that baleen whales, although they feed in more northerly waters during the Antarctic winter, lose weight while doing so.

The second problem concerns the short and medium term response of the system to krill harvesting. Only if krill production is effectively independent of density can a harvest be sustained without danger of over-exploitation. In the draft statement it is emphasised often that the krill harvest will be at the expense of the predator populations who will be expected to adjust their populations to some reduced abundance. What does not appear to be recognised is that the time scale of such adjustment in

52 such long lived species is likely to be rather long. Accordingly the total amount of food consumed by predators is likely to drop little following the start of harvesting (although as discussed earlier their energy balance will be worsened). Hence the harvest will be additive to total predator consumption, the effect of this on krill abundance will thus depend on whether krill is capable of showing a density dependent response in recruitment. This itself depends on whether the predators are keeping krill at or below its M.S.Y. level. If they are, then no density dependent response is possible and the extra harvest will tend to produce a decline in krill abundance from year to year. With the time lags in both krill and predator recruitment this would not show immediately in the system and any possible equilibrium level of krill and predators at some harvesting regime will be "overshot" both krill and predators reaching greater levels of depletion than that predicted. This problem does not appear to be recognised in the draft statement. Instead there appears the statement Appendix C p.26.

> "My present educated guess for a sustainable yield, based on possible replacement rates and ecosystem interactions, is 30 to 60 x $10^6$ tons per year for the Southern Ocean, with the larger value less likely to be sustainable over a long time."

If any meaning is to be attached to this, it presumably implies that a more conservative estimate of yield should be applied for a long term quota than for a short term one. The simple dynamic considerations detailed above suggest the reverse.

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UNIVERSITY OF MAINE at Orono
Department of Oceanography

21 February 1978

Mr. William Mansfield, III
Office of Environmental Affairs (Room 7820)
Department of State
Washington, D.C. 20520

Dear Mr. Mansfield:

Mr. John Robinson of the Center for Law and Social Policy in Washington, D.C. (I am not sure what affiliation it has) asked if I would review the "Draft Environmental Impact Statement for a Possible Regime for Conservation of Antarctic Marine Resources" prepared by your office. My comments follow. I wish to state here that I believe the document is very good. I am also very pessimistic about the possibility of negotiating a conservation treaty. We have not even been able to do it in our own country.

Notes and Comments

53 Page 13, first paragraph: The Antarctic Convergence (or Polar Front) is really a surface phenomenon only, affecting water masses down to a few hundred meters. There are large amounts of subsurface Antarctic waters which extend as far north as the latitudes of Florida. The convergence is, therefore, a boundary for many surface and epipelagic organisms, but not for deep-water or benthic animals. This is a minimum point and does not affect the workability of the proposed regime limits as set forth in the document.

54 Page 20, last paragraph: I am puzzled by the statement "Because of the scarcity of larvae in the zooplankton, fish stocks are thought to be low in the Antarctic (Gulland, 1970)." I checked in Gulland's paper and could not find any statement to that effect. Further, there are not many planktonic fish larvae because most species lay relatively few large demersal eggs and the young do not leave the bottom. We do not know anything about the mortality and recruitment rates for Antarctic fishes and such reasoning, if based upon comparisons with other regions, may be entirely fallacious. Stocks may, in fact, be low (I don't know), but probably for entirely different reasons (limited area of continental shelves, depth of shelf, etc). I know of no successful study attempting to directly measure stock sizes.

Page 58: With regard to committment of resources, I wish to urge that this country initiate a coordinated and better defined research effort in Antarctic marine biology. At present our efforts consist

almost entirely in the Hero and Islas Orcadas programs of the Division of Polar Programs of the National Science Foundation. The Hero is small and tied to the activities at Palmer Station, but if properly used could be the platform from which much good basic fishery research could be carried out in the area of the Antarctic Peninsula. I have heard many complaints about the ship - its design, the arrangement and priorities of laboratory space, and the condition of the winches - but since I have never seen the vessel I am not competent to comment further.

I have participated in several cruises on the other vessel, both when it was called the USNS Eltanin and after it was renamed the Islas Orcadas. The present joint Argentine - U.S. program is very inefficent, providing as it does only 100 days of ship time per year at a relatively high cost. The nature of the program makes it impossible to carry out fisheries research because of the severe time limitations and competition for use of the vessel. The vessel is a good one (or at least was when I was last aboard) but it is being used at about one-third its potential.

Good fishery research (stock estimates, age structure of species, etc.) requires at least an initial period of repetative sampling. This is impossible under the present Islas Orcadas program and possible (but not, to my knowledge, ever done) for a restricted area with the Hero. The U.S. needs to have a ship-supported research program aimed at the living resources of Antarctica which can be coordinated and efficiently run. I do not believe that either the Russians or Japanese (or the East and West Germans or Poles) will initiate sound fishery research programs because their efforts are too closely bound up with the industry (this may not be true for West Germany). There is no historical evidence that the eastern European nations or Japan will make serious efforts to institute a conservation regime or the supporting research.

To finish, I am very pleased that efforts are beginning toward creating an international conservation vehicle. I am pessimistic about its becoming a reality, and I have the feeling that the kinds of pressures the Antarctic Treaty is beginning to feel presage its end. I feel incredibly lucky to have been able to see and work in the Antarctic before this time.

Sincerely yours,

Hugh H. DeWitt

Hugh H. DeWitt, Chairman
Associate Professor

HHD/jn

DePaul
UNIVERSITY

DEPARTMENT OF BIOLOGICAL SCIENCES
1036 WEST BELDEN AVENUE
CHICAGO, ILLINOIS 60614
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April 19, 1978

Mr. William H. Mansfield III,
Office of Environmental Affairs,
Department of State,
Washington, D.C. 20520.

Dear Mr. Mansfield:

Upon my recent return from Antarctica (Palmer Station) I found "The Draft Environmental Impact Statement for a Possible Regime for the Conservation of Antarctic Living Marine Resources", February, 1978. Thank you for this copy.

Your invitation for comments is appreciated and I recognize it is past 3 April (that date I was still in the Drake Passage!). However, reading the sections on krill I cannot help but note for the record some observations which are at variance with some made in that "Statement";

55 pg. 22, para.+6. Krill are not herbivores; they are omnivores and cannibals. These habits occur continuously throughout the austral summer while phytoplankton stocks are also being used.

56 pg. 23, para.$^{+}$ 2. There is no evidence for, nor has there been any statement made by those who study krill, that different krill consumers/predators feed at different geographical regions, --- times of year, --- different size classes of krill, (except by Green who has not had an opportunity to study them). All available data indicate otherwise; i.e., our recent study of stomach contents of crabeater seals (*Lobodon carcinophagous*) show they eat krill ranging from adolescent (21mm) to gravid mature,(45mm); our findings with minke whales are the same. There is no statement concerning dependence of Leopard seals on krill. Their diet is reported to be 80% krill (Oritsland, 1977).

57 pg. 23, para.$^{+}$ 5. The breeding area is well known to be geographically spread; hardly only in the Scotia Sea. We studied spawning females taken from the eastern Bellingshausen sea, the Bransfield Straits, and the western Scotia Sea. Moreover, these occur from late Nov. to late Mar. A seasonal limitation on

harvesting will therefore in some way have to reckon with this.

There is no mention made of the Japanese and Taiwan krill fishing areas; ca. 20° to 120°E.

pg. 27, para.$^{+}$ 1. It is interesting to note that early February 1978, ca. 35 Russian ships gathered in Gold Harbor, of So. Georgia to determine whether to continue fishing in the light of such a poor catch to that time this season. Allegedly, they departed Antarctica. Additionally, the FRG *Walter Herwig* and its companion trawler, *Julius Foch* were unable to locate sites of satisfactory commercial stocks this season (Gotthilf Hempel, Expedition Science Leader, FRG *Walter Herwig*, personal communication, Jan. Feb. 1978). I have not found any serious attention given to such (apparent) annual fluxes in krill stocks (including pgs. 31 and 32).

pg. 32, para.$^{+}$ 4.
pg. 35, para.$^{+}$ B.2.
pg. 36, para. 1.

One would hope that the proposed federal action would require (vs. "encourage") scientific investigation. For example, it is promulgated that krill females produce 300-800 eggs (Mauchline and Fisher, 1969) and then die (Bargmann, 1945; Marr, 1962). We now know that they release 2000-3000 eggs per spawn (= fecundity) and do not die but revert to a "young" condition and most probably spawn again, and --- in the same season. The impact of this difference in *potential* annual recruitment level is clear and it will play ultimately on annual harvestable limits, and knowledge to estimate the MSY and true sustainable yield. Only a vigorous scientific program will provide the best data for a convention relative to this aspect of krill biology and many others, i.e., longevity, growth rates, etc.

pg. 34, para.$^{+}$ 4.
pg. 35, para. B.2.

Our recent study strongly points to at least two different breeding stocks west of the Antarctic Peninsula; if the data become overwhelming then most assuredly, the So. Georgia stock will also be different. The Convention should take cognizance of this and it becomes imperative to discover the longevity and spawning potential of each stock. This is basic science. Fishing/harvesting/samples therefrom, will not necessarily disclose these differences; basic biological studies will.

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pg. 36 para.$^+$ 2. All known efforts to develop a profitable commercial fishery (pg. 26. 4.) should provide some question when one reads "krill harvesting ---- 20,000-40,000 tons per year". The last reported catch figure of USSR (1974) was 20,000 metric tons. It is unrealistic (4 years later and 10 nations fishing) to accept this (stated) range as the present combined harvest. It is well known that Nations realize this is a sensitive subject and with great reluctance disclose catch tonnage (i.e., Oyama, Far Seas Fisheries Lab., Shimuzu, Japan, stated the 1977/78 projected catch was to be 25,000 mt; pers. comm.)

pg. 38 para.$^+$ 3. There is no evidence for, nor theoretical basis for, "--- increased krill abundance resulting from reduction in whale populations". Indeed, this contradicts the basic thesis promulgated elsewhere in this "Statement"; i.e., pg. 23; pg. 28; pg. 37, etc.

pg. 38-39. Consider the potential of a krill processing plant at the Polish Station Arctowski; at Puerto Williams on the Beagle Canal (Chilean-French); at Rio Grande, Tierra del Fuego (FRG), (all very likely).

pg. 39. I wonder if 54 ships off the coast of So. Georgia (Jan. 1978), "---- shipping traffic --- krill harvesting (is really) very low"?

pg. D-1 para.$^+$ 5. It is unlikely that nauplii or metanauplii rise in the water column; they "fall to the bottom" in the laboratory; indeed, they move but cannot swim.

pg. D-5 para.$^+$ 2. Successful development occurs at "sea level" (in the lab.). There is no developmental requirement for depth.

I apologize for the sketchiness of these comments but as they are too late anyway, it is perhaps of less importance. Once again, thank you for sending a copy of this "Statement".

Sincerely,

M. A. McWhinnie

M. A. McWhinnie, Ph.D.
Professor

MAM:vo

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14 April 1978

Mr. William H. Mansfield III
Office of Environmental Affairs
Department of State
2201 C Street N.W.
Washington, D.C. 20520

Dear Mr. Mansfield:

I have just read with considersble interest the draft "Environmental Impact Statement for a Possible Regime for the Conservation of Antarctic Living Marine Resources." The accompanying letter states that comments will be accepted until 3 April. However, the report did not come to my desk until the 13th so I thought under those circumstances you might still be receptive to yet one more letter.

I am in general agreement with the action being proposed. However, because the U.S. has no vested commercial interest in the Antarctic resources at this time, won't it be difficult for us to enforce any such agreement? Perhaps my naivete about international law leads me to think this, but the EIS implies that the U.S. is the initiator and implimentor of any action. Is this the case? Or is this draft EIS merely a position document?

Also, quantitative data appear lacking in the EIS. The SCAR and SCOR reports that accompany the draft EIS suggest that considerable work is complete or is underway, but I surmise that too few data are available to draw definite conclusions about stocks in Antarctica. Perhaps an EIS should be postponed until data are sufficient to provide greater confidence in stock estimates.

I think it is commendable that the U.S. sponsors research in this part of the world ocean. I would like to know if there are aspects of this research that a company such as OSI could undertake. Does the Department of State solicit proposals for such marine work, or is this handled by someone else, e.g. the United Nations? Or is all the work conducted under grants to Universities? Reference to a study by Tetra Tech leads me to think otherwise.

Thank you for the opportunity to review this important document. Please keep my name on your mailing list for future publications. Also thank you in advance for considering my questions.

Sincerely,

Donald A Scott

Donald A. Scott
Biological Oceanographer

ejw

# Comments on the
# "Draft Environmental Impact Statement for a Possible Regime for Conservation of Antarctic Living Marine Resources"
(Department of State, February 1978)

by

Drs Rudiger Wolfrum & Frederick S. Tipson
Center for Oceans Law and Policy
University of Virginia

The effort to develop a regime for the management of Antarctic Living Marine Resources seems to us to have two, somewhat-different dimensions: the nature of the proposed scheme itself, and the relationship of this effort to the increasingly delicate regime governing continental Antarctica. In our view, efforts to proceed with the former regime should not be allowed to jeopardize or create confusion about the nature or future of the latter. We have no doubt that the Department of State has given careful consideration to this relationship, but we are concerned that the DEIS may be a bit misleading in certain respects. Therefore, we offer some preliminary comments on the larger American interests in the Antarctic area before addressing the specific issues of a regime for the living marine resources.

## Preserving the Continental Regime

Whatever commercial interest the United States itself may some day develop in exploiting the living resources (it seems not to have any now), that interest is clearly outweighed by its interest in protecting the Antarctic environment and preserving the key features of the existing treaty regime for the continent: demilitarization, coupled with open inspection; wide access for research and exploration; and reservation of its own possible claims to resource exploitation (and even sovereign control) should the existing regime ever deteriorate or be modified to allow such developments. Whether or not the exploitation of mineral resources is to be allowed in the future--and we do not comment on the desirability of that here--we would suggest that this issue be kept strictly separate from the question of living resource exploitation offshore. It should be made clear that the living resource regime does not extend to resources on the continental margins of Antarctica which, in our view, should be considered as part of the area covered by the Antarctic Treaty. Similarly, the southern extent of the "high seas" included within the living resource regime should not be defined in terms of a uniform zone of 12, 200, or some other mileage limitation which might be taken to prejudge the status of the adjacent Antarctic territory. We would suggest instead that the

"high seas" in question be understood to extend to the line of solid ice, except that the Scientific Committee on Antarctic Research (or whatever scientific body is designated under the future regime) should be asked to recommend areas of adjacent waters to be excluded from fishing or processing operations in the interests of preventing adverse environmental impacts to the waters themselves or to the mainland. Presumably, such restricted areas would include virtually all waters immediately adjacent to the mainland, but these should be of varying breadths and locations according to local conditions and the areas already protected. Such designations should also be subject to appeal on the basis of scientific evidence, though the standard for protection should be weighted heavily toward protection of the environment.

Furthermore, the United States should oppose the location of any shore-based factory facilities on the mainland of Antarctica, as apparently envisioned on pages i and 38-39 of the DEIS. These, we believe, would be incompatible with the present continental regime and would undoubtedly result in damage to the unique Antarctic environment. Shore-based communication facilities are also mentioned in relation to commercial operations; at the very least, these should only be authorized by the Contracting Parties to the Antarctic Treaty in the interests of preventing accidents or or other incidents which might jeopardize the mainland environment.

In short, though the marine living resource issue should be strictly separated from that of the mainland, the potential areas of interaction should be carefully considered and provided for in developing the new regime. Of course, the question of whether to spell out all these considerations and conclusions in a public document is largely a tactical one.

## Developing a Regime for Living Marine Resources

Our recommendation for the living marine resource regime itself is to fashion a comprehensive management scheme similar to the one recommended in the DEIS, but composed of all sub-60 degree fishing nations, the Contracting Parties to the Antarctic Treaty and the members of the two bodies dealing with migratory species in the area: the International Whaling Commission and the members of the Convention on Antarctic Sealing (the latter are, of course, coincident with the Antarctic Treaty members.) Since Article VI of the Antarctic Treaty specifically excludes the high seas areas south of 60 degrees latitude from its coverage, these matters should be governed under the present Geneva Conventions on the High Seas and on Living Resources--both of which are compatible with any foreseeable outcome of the Third U.N. Law of the Sea Conference. In other words, we would approach this matter on the basis of a specialized fishery organization, built around the fishing nations, but giving special regard to the Antarctic Treaty countries (as the equivalent of "littoral" or "coastal" states under the Geneva Convention on Fishing and Conservation of the Living Resources of the High Seas) and those with interests in Antarctic marine mammals. "User" interests alone would not dominate under such a regime, but neither would the arrangement be open to voting membership by large numbers of other countries. (Alternatively, membership might be open to all, with effective decision-making limited to specialized panels created to deal with individual species, as in the International Commission for Northwest Atlantic Fisheries. For various reasons, however, this approach seems less desirable. Likewise, the International Whaling Commission model does not seem suitable.) This question is of considerable importance since the composition of the new international organization will strongly influence its operation. Only the participaton of non-users in the decision-process will provide for the necessary balance of interests. It is to be expected, following the IWC example, that non-users would tend to be more adamant in protecting the environment of the Antarctic sea. Nevertheless, since we do not propose that the new organization be open to all states, the users need not fear being routinely overruled.

The second major issue after membership is that of a voting formula. Again, the example of the various regional fisheries
60 organizations suggests two major problems: disputes over the state of the stocks under management and the limited effectiveness of catch restrictions where states can object and thereby "opt out" of the restrictions. Obviously, a difficult balance must be struck so as to encourage membership without at the same time diluting the effectiveness of the management system. We would suggest, first, that all stock information be collected and evaluated by an independent scientific council (SCAR or some equally objective group) as in the IWC. If a really effective system is to be established, it is essential to have a completely independent council of scientific experts whose recommendations would be binding unless overrruled by some extraordinary majority. Catch limitations or allocations would thereby be routinely established on the basis of the scientists' recommendations. Fishing states would have a right to object and avoid such limitations only where they were imposed by a less than two thirds majority of those member-states present and voting. Here we propose a change from the procedure which is normally used by fishery organizations (ICNAF, NEAFC, ICSEAF, ICCAT, IWC). This can be justified on two grounds. As the membership of the new organization includes all concerned interests and seeks a fair balance among them, the users should not be allowed to avoid the outcomes of the decision-making process. Second, as all recommendations are to be based on scientific findings, there is no reason why a user should have the right to endanger the total stock through overfishing--particularly in the early years of operations when all data will be especially tentative. Finally,

enforcement would follow the model of ICNAF--a "joint enforcement system" under which any treaty party would have the right to inspect the ships of any other party.

We recognize the problems of negotiability with respect to several of the above suggestions, but hope that these thoughts will be useful both in preparing the final EIS and in developing future American policy.

Rudiger Wolfrum
Frederick S. Tipson
April 1, 1978*

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# APPENDIX J

## DEPARTMENT OF STATE
## RESPONSES TO COMMENTS
## BY
## FEDERAL AGENCIES, PRIVATE ORGANIZATIONS
## AND INDIVIDUALS

The Department's responses in this appendix are keyed to the marginal numbers in Appendix I.

1. A summary of available information on krill exploitation can be found in Tetra Tech, 1978. It is difficult to get current catch records for exploratory krill fishing and detailed plans for proposed exploitation are not available.

2. This EIS is concerned with impacts of different harvesting regimes. The potential impact of activities associated with development of nonliving resources is acknowledged at the beginning of Chapter VI.

3. Emphasis on uncertainty in standing stocks and production rates, and on harvesting of krill predators rather than krill, has been added in section VI.B.5 V. E.

4. Maps of productive areas can be found in El-Sayed (1970) and Balech et al (1968).

5. Chapter III of the Final EIS has been revised to reflect in part the points raised here. A summary of the general subject matter of the conventions collectively has been added, along with the addition of information relating to whether the United States is a party to the conventions.

6. Discussion of the Department's actions to obtain and consider non-governmental comment before and during the Canberra negotiating session and to use the Draft EIS comments during the continuing international negotiations on the possible regime are detailed in Chapter XI of the Final EIS and outlined in responses to comments 35 and 36. The Department considered the possibility of issuing supplementary information to the Draft EIS following the Canberra meeting, but concluded that the meeting did not significantly change the factors presented in the draft so as to warrant publication of a supplementary Draft EIS.

7. The existing potential capacity for overexploitation of krill is indicated in section VI.A.2.

8. A discussion of time lags in the ecosystem structure has been added to section VI. A. 2.

9. Although this EIS deals with the question of harvesting impacts on the Antarctic ecosystem, an acknowledgement of potential future concerns of environmental impacts due to activities associated with development of nonliving resources has been added in the beginning of Chapter VI.

10. Section V. D. on areas of special biological importance has been expanded.

11. Migratory species are discussed under section V. B.3, 4 and 6.

12. Section VI.A1 has been expanded to include the statement that only member nations are bound by the policies developed under the International Whaling Convention and the Convention for the Conservation of Antarctic Seas.

13. This response is keyed to the overall discussion of the proposed Federal action and alternatives contained in the Commission's letter, pp. 1-9.

    The Final Environmental Impact Statement incorporates revisions in the section dealing with the proposed Federal action (Chapter I) and the alternatives to it (Chapter II). These revisions, and in particular the considerably more detailed description of the proposed Federal action, reflect the development of specific United States positions for the first round of international discussions on a regime to conserve Antarctic marine living resources, held in Canberra, February 27-March 16, 1978. Development of specific U.S. positions took place in light of preliminary comments received on the Draft Environmental Impact Statement, including those put forward by the Marine Mammal Commission.

    The Final EIS, we believe addresses the major points raised by the Marine Mammal Commission. The proposed Federal action is set forth in more concrete form (recognizing that the final outcome of a negotiation cannot be predicted early in the negotiating process). Further, the alternative course of action suggested by the Marine Mammal Commission is, in its major components, consistent with the proposed Federal action, not an alternative to it. The refinement of the proposed Federal action in the Final EIS includes provisions congruent with points 1, 3, 4 and 5 of the Commission's suggested alternative (pp. 7-8 of its comments). The proposed Federal action does not incorporate point 2 in the sense of calling for all harvesting in the immediate future to be limited and designed as part of a scientific research program. This would be the equivalent of a moratorium on harvesting unless pursuant to a scientific research program and, as pointed out in both the Draft and Final EIS, it is not possible to secure international agreement on a moratorium.

    In addition the Final EIS broadens the concept of "interim measures" included in the second of the two suboptions presented with the proposed Federal action in Chapter I. This revision is based in part upon the difficulties in the original treatment pointed out by the Commission.

    Finally, The Commission's comments on these sections refer to difficulties resulting from uncertainties caused by lack of data regarding Antarctic marine living resources and the Antarctic marine ecosystem. The Draft EIS, as well as the final statement, appear to adequately identify and reflect these uncertainties -- both in the body of the statements and in their appendices. These data gaps and the necessity to make estimates upon the best available, though undoubtedly incomplete, information are inherent in addressing the issue.

14. Responding to the discussion on pp. 9-11 of the "Relationship of the Proposed Federal Action to International Agreements with Implications for the Antarctic Environment", the EIS has been rewritten to incorporate revisions to deal with a number of the points raised, including those relating to U.S. domestic legislation. The descriptions of international agreements relating to Antarctica has been expanded and updated. The Commission refers to the importance and value of close ties between the regime to conserve Antarctic marine living resources and the International Union for the Conservation of Nature (IUCN). The proposed Federal action, as revised in its description in the Final EIS, refers to the IUCN as a non-governmental body with which the conservation regime should establish cooperative relationships.

15. A comment on the need to account for risks associated with uncertainties in information in designing conservation measures for the Antarctic marine ecosystem has been added to section VI.B.5.

16. The discussion of conservation objectives in Chapter I has been revised to clarify that although whales are the best known of Antarctic resources, knowledge of them is still incomplete.

17. Section V.B.5 has been corrected in accordance with this comment.

18. References have been added to Section VI.B.6.

19. The discussion of the potential impact of krill harvesting on whale population dynamics in section VI. A.3. has been expanded.

20. Section V.C.has been modified as suggested.

21. Appendices E and F contain a full discussion of the range of estimates of krill population and productivity and of uncertainty in the estimates.

22. The concept of alternate food pathways or different ecosystem equilibrium points has been added at the end of section VI.A.3.

23. Section V.D.on areas of special biological importance has been expanded.

24. The arrow leading from crabeater seals to the compartment with other Antarctic pinnipeds in Figure 2 is intended to indicate possible predation on juvenile crabeater seals by leopard seals.

25. Discussion of the history of seal harvesting in section V.E.2 has been revised.

26. Section V.E.4. has been revised as suggested.

27. Section V.F.has been revised to include scientific research in Antarctic waters prior to the Antarctic treaty.

28. Section V.I.has been expanded to include a mention of marine plants as potentially harvestable resources even though at present there is no apparent commercial interest in these groups.

29. The discussion of impacts of harvesting on krill populations in section VI.A.2. has been expanded as suggested.

30. This inaccuracy has been corrected in the Final EIS.

31. The Final EIS incorporates a considerably revised description of the proposed Federal action in Chapter I. The revision results from development of specific U.S. positions for the first round of international discussions on a regime to conserve Antarctic marine living resources held in Canberra, February 27-March 16, 1978. This revision appears to meet the comments made in point one of the Center's reaction to the Draft EIS.

32. The desirability of limitations on harvesting in the period between negotiation and ratification of the proposed regime has been indicated in section VI.B.5.

33. The Final EIS incorporates a revised section in Chapter I of the suboptions attendent upon the proposed Federal action, specifically to expand the concept of interim measures. The U.S. supports suboption two. At the same time, the Department of State disagrees that suboption one is totally unacceptable. It is true that suboption one poses greater risks to the environment than suboption two, particularly if the regime were to take many years to come into force. However, inability to fully achieve all U.S. objectives with regard to suboption two does not necessarily render a regime reflecting the proposed Federal action unacceptable.

34. The Department of State agrees with the view that the UN Food and Agriculture Organization should have a major role in the conservation regime to be negotiated. We believe this point is adequately reflected in both the Draft and Final EIS. It is the Department's view that a conservation convention cannot resolve questions relating to the distribution of resources which may be harvested from Antarctic waters. We would, of course, hope if these waters offer a major new source of protein on a continuing basis that it could contribute to meeting world protein shortages.

35. Departmental officials understand the desire expressed in the comment for earlier publication of the Draft EIS to allow more timely comment. The timing and course of diplomatic discussions involving a number of

other nations do not always provide us with the flexibility we would like to carry out such procedures. To provide greater opportunity for comment on the Draft EIS, however, the Department held a public meeting to solicit public views on the possible Antarctic marine living resources issue in Washington, D.C. on December 20, 1977. On February 10, 1978 before the international negotiations on the possible regime began the Department held another public meeting in Washington, D.C. to receive oral comments on the Department's draft impact statement. Transcripts of these meetings are included in Appendices B and C of this EIS. The views given at these meetings were taken into account in developing the U.S. Government position in the negotiations at Canberra. Additionally, knowledgable public members were part of the U.S. delegation at the international negotiations at Canberra in February. Inasmuch as the international negotiations are continuing, written comments received on the Draft EIS are being considered in the negotiation process.

36. The Department made early and full distribution to involved Federal agencies, private organizations and individuals interested in Antarctic matters. Copies were sent also to all individuals who requested them. Full distribution will be provided for the final EIS.

37. As expressed in the Draft and Final EIS, we believe that alternative E -- the moratorium alternative -- is non-negotiable. In other words, it is likely in our considered view that exploitation will take place. In such a case, one of the main objectives of a conservation regime is to provide the necessary obligations and machinery to ensure that sufficient data is obtained to properly regulate harvesting.

38. The conservation regime envisaged in the proposed Federal action would include an illustrative, non-exhaustive list of possible conservation measures. It would not include specific reference to national allocations and the Department of State does not believe such specific reference can be agreed in the negotiations. The conservation regime envisaged in the proposed Federal action, however, would not preclude development of national allocation systems when the need for these systems arises.

39. The Final EIS has been written to take account of this view.

40. The Final EIS has been written to accommodate this point.

41. The Final EIS has been written to accommodate this point.

42. See comment 34 above.

43. Section VI.A.2. has been revised to include the existing potential capacity to overexploit krill populations with a redeployment of large fishing fleets.

44. The Department believes that the conclusion expressed in the Draft EIS -- that the moratorium alternative E is non-negotiable -- remains valid. The Final EIS reflects this conclusion. Regarding the question of national allocations, the proposed Federal action, which as you will note has been revised considerably in the Final EIS, is not inconsistent with development of a system of national allocations within the conservation regime.

45. The question raised in this comment has been brought up in earlier comments; please see the responses in answer 35 above, and in the Final EIS Chapter XI on Consultation and Coordination in the preparation of the EIS. The public meetings held before and after the issuance of the Draft EIS proved useful both in preparing the EIS and the U.S. position for the Canberra international meeting.

Comments on the Draft EIS and indeed on the final document will be valuable to U.S. decision-makers in the ongoing discussion and negotiation of the possible regime.

46. Please refer to response 35 to an earlier comment on the question of timeliness. Also refer to the final EIS Chapter XI on public meetings on consultation on preparation of the U.S. position on the regime and the Final EIS. We believe that these meetings, comments and informal discussions with a wide range of interested individuals provided the opportunity for adequate non-governmental input into the U.S. position on the conservation regime.

47. This response deals with comments on points 3, 4, 5 and 6 in the letter desling with alternative courses of action. As is noted in the Draft EIS the alternatives for a regime to conserve Antarctic marine living resources form a continuum. Delineation of specific alternatives along this continuum obviously involves a degree of selectivity if reasonable alternatives are to be delineated. The Department disagrees with the National Audubon Society's view that the listing of alternatives is inadequate. We believe that they do represent a description of the reasonable options available to policy makers.

The Society's comment also asserts that the proposed resource regime, as described in the Draft EIS, is "first and foremost a fisheries regime". The Final EIS incorporates a revised description of the proposed Federal action which makes clear the objectives and standards of the proposed conservation regime. It should be noted, however, that the view set forth in the Draft EIS that a moratorium is non-negotiable remains valid. In other words, it is likely that exploitation will take place. In this situation, one of the major objectives of a conservation regime is to provide the necessary obligations and machinery to ensure that sufficient data is obtained to properly regulate harvesting.

The letter refers to deficiencies in the second suboption of alternative D. The Final EIS includes a revision in the portion dealing with this suboption designed to meet points such as those raised by this comment.

48. As indicated in response to similar comment above (6) the Department considered the need for preparing a supplemental Draft EIS after the Canberra meeting, and concluded that the meeting did not lead to alterations in the information presented in the Draft EIS which were significant enough to warrant preparing a Supplemental Draft EIS.

49. Please see the response to the Marine Mammal Commission comments on this subject, 7-29.

50. A possible response of the entire system structure to krill harvesting has been added to section VI.A.3.

51. The discussion of whale population dynamics and their relationship to krill harvesting in section VI.A.3. been expanded.

52. A discussion of varying time scales of response to krill harvesting in different predator populations has been added to section VI.A.2.

53. Section V.A.1. has been revised to take this point into consideration.

54. Section V.B.3. has been corrected.

55. Section V.B.has been revised to indicate the omnivorous feeding behavior of krill.

56. Section V.C.has been revised in accordance with this information.

57. Section V.B.1. and section IV.D. have been revised to take this information into account.

58. Section V.E.4. has been revised to indicate uncertainties in catch levels for recent years.

59. The proposed Federal action seems to be consistent with the views expressed in the comment.

60. On the membership and voting issues, the proposed Federal action includes an accession formula under which states engaged in research on, or harvesting of Antarctic marine living resources could become parties to the regime. Such a standard is designed to ensure maximum effectiveness of the regime, including a balsnce between "users" and "non-users" with direct interest in the resources and the Antarctic marine environment as a whole. The suggestion in the comment on voting is useful. At this stage in the international negotiation, however, it is not possible to determine what specific voting pattern will achieve the necessary agreement. The proposed Federal action refers to "an effective decision-making system". This is primarily a mstter of negotiation. The U.S. will continue to seek a voting formula for the regime within which conservation decisions will be taken on the basis of objective scientific criteria and data and one which will lead to implementation of effective conservation measures. The proposed Federal action, it should be noted, includes a system of international observation and inspection.